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ABSTRACT

This technical specialty course is one of thirty-five courses designed for use by two-year postsecondary institutions in five nuclear technician curriculum areas: (1) radiation protection technician, (2) nuclear instrumentation and control technician, (3) nuclear materials processing technician, (4) nuclear quality-assurance/quality-control technician, and (5) nuclear reactor (plant) operator trainee. This course, Mechanical Component Characteristics and Specifications, contains eight modules: Pump Characteristics and Specifications, Piping Characteristics and Specifications, Valve Characteristics and Specifications, Fastener Characteristics and Specifications, Lifting and Handling Equipment Characteristics and Specifications, Rotating Equipment Characteristics and Specifications, Heat Exchanger Characteristics and Specifications, and Pressure Vessel Characteristics and Specifications. Each module follows a typical format including the following sections: introduction, module prerequisites, objectives, subject matter, exercises, materials, procedures, data tables, reference materials, and tests. (A master index and suggested program planning guides are also available--see CE 026 856 and CE 026 639-643.) (LRA)

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ED192150

Nuclear Technology Series

COURSE 16

MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

TECHNICAL EDUCATION RESEARCH CENTER - SW

4201 LAKE SHORE DRIVE - SUITE 111

WACO, TEXAS 76710

CE 026 782

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OCT 1980

P R E F A C E

ABOUT NUCLEAR TECHNOLOGY MODULES

The modules - developed by TERC-SW for use in two-year postsecondary technical institutions to prepare technicians for employment - are useful in industry for updating employees in company-sponsored training, and as laboratory texts in engineering schools. The principles, techniques and skills taught in the modules, based on tasks that nuclear technicians perform, were obtained from a nationwide advisory committee of employers of nuclear technicians. Each module was written by a working technical expert and tested with students.

A module contains the following elements:

Introduction, which identifies the topic and often includes a rationale for studying the material.

Module Prerequisites, which identify the material a student should be familiar with before studying the module.

Objectives, which clearly identify what the student is expected to know for satisfactory module completion. The objectives, stated in terms of action-oriented behaviors, include such action words as operate, measure, calculate, identify and define, rather than words with many interpretations, such as know, understand, learn and appreciate.

Subject Matter, which presents the background theory and techniques supportive to the objectives of the module. Subject matter is written with the technical student in mind.

Exercises, which provide practical problems to which the student can apply this new knowledge.

Materials, which identify the equipment required to complete the laboratory procedure.

Procedures, which is the experiment section, or "hands-on" portion of the module (including step-by-step instruction) designed to reinforce student learning.

Data Tables, which are included in most modules for the first year (or basic) courses to help the student learn how to collect and organize data.

Reference Materials, which are included as suggestions for supplementary reading, viewing for the student.

Test, which measures the student's achievement of the prestated objectives.

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The Nuclear Technology Series will consist of five curricula when completed:

Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Nuclear Quality-Assurance/Quality-Control Technician.
Nuclear Instrumentation and Control Technician.

The completed Nuclear Reactor (Plant) Operator Trainee curriculum consists of the following sixteen technical specialty courses made up of 114 instructional modules:

Radiation Physics.
Radiation Protection I.
Principles of Process Instrumentation.
Heat Transfer and Fluid Flow.
Introduction to Nuclear Systems.
Instrumentation and Control of Reactors and Plant Systems.
Reactor Operations.
Reactor Safety.
Reactor Auxiliary Systems.
Power Plant Systems.
Radiation Detection and Measurement.
Reactor Physics.
Power Plant Chemistry.
Introduction to Quality Assurance/Quality Control.
Metallurgy and Metals Properties.
Mechanical Component Characteristics and Specifications.

Availability: Instructional modules are available individually or by courses from:

Technical Education Research Center - Southwest
4201 Lake Shore Dr., Suite 111
Waco, Texas 76710
Telephone (817) 772-8756

Printed:

CONTENTS

Preface

Module 16-1 Pump Characteristics and Specifications

Module 16-2 Piping Characteristics and Specifications

Module 16-3 Valve Characteristics and Specifications

Module 16-4 Fastener Characteristics and Specifications

Module 16-5 Lifting and Handling Equipment Characteristics and Specifications

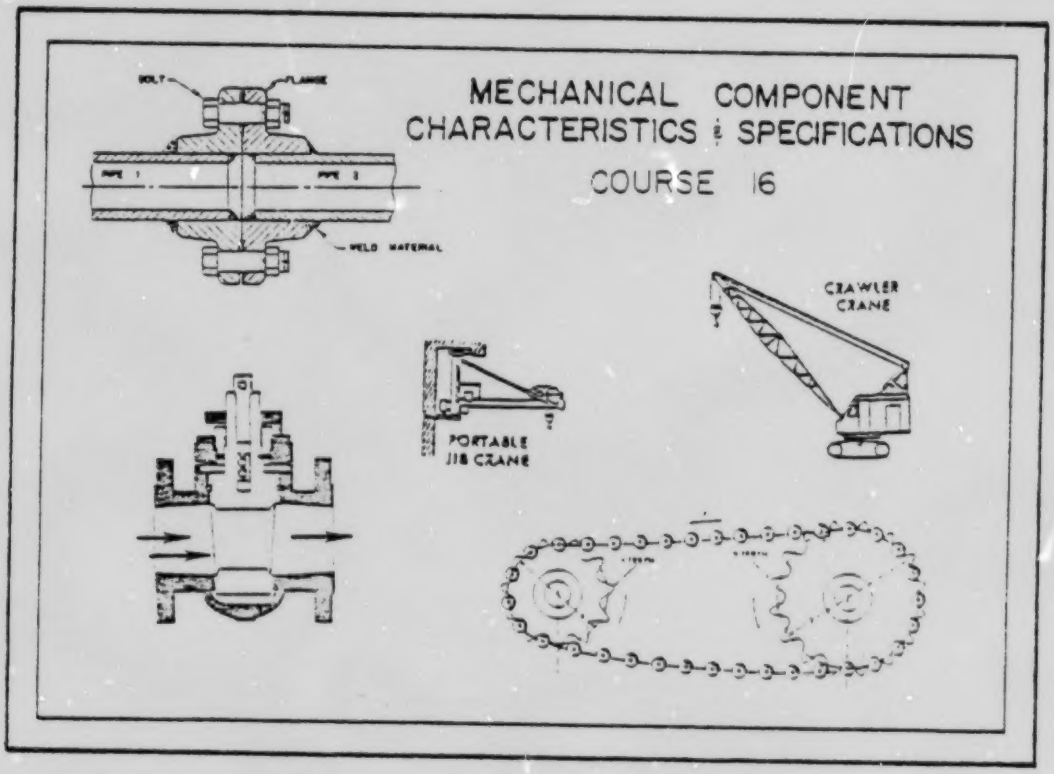
Module 16-6 Rotating Equipment Characteristics and Specifications

Module 16-7 Heat Exchanger Characteristics and Specifications

Module 16-8 Pressure Vessel Characteristics and Specifications

NUCLEAR TECHNOLOGY

MODULE 16-1 PUMP CHARACTERISTICS AND SPECIFICATIONS



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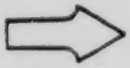
TECHNICAL EDUCATION RESEARCH CENTER — SOUTHWEST
4201 LAKE SHORE DRIVE WACO, TEXAS

COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS



MODULE 16-1 Pump Characteristics and Specifications

MODULE 16-2 Piping Characteristics and Specifications

MODULE 16-3 Valve Characteristics and Specifications

MODULE 16-4 Fastener Characteristics and Specifications

MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications

MODULE 16-6 Rotating Equipment Characteristics and Specifications

MODULE 16-7 Heat Exchanger Characteristics and Specifications

MODULE 16-8 Pressure Vessel Characteristics and Specifications

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A pump is a mechanism designed to draw fluid into itself through an entrance port and to force the fluid out through an exit port. In effect, pumping is the addition of energy to a fluid to move it from one point to another. Since the function of energy is to do work, addition of energy to a fluid causes the fluid to do work (such as flow through a pipe or rise to a higher level).

Mechanical pumps deliver fluid by direct contact with a moving part of the pumping machinery. There are two basic types of mechanical pumps:

Velocity machines - either centrifugal or turbine pumps, which impart energy to fluid by increasing its velocity; the energy is then converted into pressure, or head.

Displacement machines - with plungers, pistons, cams, or other devices that act directly on fluid, forcing it to flow against a higher pressure.

An electromagnetic pump is used when direct contact between fluid and pumping is not desirable. Because it has no moving parts, an electromagnetic pump is used in nuclear power plants and elsewhere to circulate liquid metals (sometimes used in reactor coolant).

MODULE PREREQUISITES

The student should have completed Module 10-5, "Pumps," from Course 10 of this series.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. List types of pumps.
2. List documents, codes, etc., that apply to pumps and their specifications.
3. Given specificatons, choose type(s) of pump(s) best suited to a given application.
4. Given pressure-flow characteristics for an application, select a type of pump best suited to that application.
5. Given a specific requirement, test various types of pumps to see which best meets specifications.

PUMP CLASSIFICATION AND USE

Pumps may be classified as follows:

Centrifugal.
Reciprocating.
Rotary.

Centrifugal pumps are used more commonly. Occasionally, however, a reciprocating pump may be more advantageous. Rotary pumps have valid but limited application, and may never be encountered in a nuclear power plant.

GENERAL CHARACTERISTICS OF CENTRIFUGAL PUMPS

Centrifugal pumps are best suited for applications requiring large capacity at any head. They can be designed to deliver any capacity, from zero to maximum, at virtually constant discharge pressure, while operating at constant speed.

GENERAL CHARACTERISTICS OF RECIPROCATING PUMPS

Reciprocating pumps are suited for applications requiring high heads and small capacities. Significantly, they have higher efficiencies than centrifugal pumps. When operating at constant speed, a reciprocating pump delivers a fixed capacity (at any discharge pressure) within its pressure rating.

A reciprocating pump can be started without priming.

CONSTRUCTION AND OPERATING CHARACTERISTICS

Because rotary pumps are less significant to this discussion, they are treated last.

CENTRIFUGAL PUMPS

A centrifugal pump is the most simple type of pumping apparatus. Mechanical power, delivered to the shaft by the prime mover, is transmitted to the liquid by means of a series of radial vanes cast together to form a single element called an impeller. The impeller is made to revolve by the shaft. Liquid flows to the inner ends of the impeller vanes, which pick up the liquid with a rapidly accelerating motion, causing the liquid to flow outward, away from the shaft in a radial pattern between the vanes. Upon reaching the outer circumference of the impeller, the liquid has absorbed all of the power transmitted to the pump shaft. This action is accomplished by picking up velocity and pressure during the liquid's travel to the outer circumference.

Upon leaving the pump, energy of the liquid mostly is in the form of pressure. This process is accomplished by changing velocity to pressure; velocity of the liquid is slowed gradually and uniformly, with the least possible loss from eddy currents and shock. The pump casing is used to achieve this velocity-to-pressure change.

The pump casing may be volute or circular with diffusion vanes. With the proper design of volute (or diffusor), it is possible to transform a large percentage of the velocity into pressure, thus the energy loss incurred is quite small.

Advantages of centrifugal pumps include an ability to handle large volumes of liquids at low heads. Centrifugal

pump size is relatively small (for any given capacity and head) because of its high rotational speed. A centrifugal pump has no internal valves to cause operating difficulties; (it is possible to obtain automatic regulation based upon capacity, suction pressure, or discharge pressure).

Liquid discharged from a centrifugal pump is delivered in a steady stream, therefore, no receiver is required to even out flow pulsations. Even if operated with its discharge valve closed (for a short period of time) no danger or failure occurs.

RECIPROCATING PUMPS

In reciprocating pumps, a piston or plunger moves back and forth in a cylinder, displacing liquid from the cylinder. Most reciprocating pumps may be classified as one of the following types:

Simplex - usually steam driven.
Duplex - usually steam driven.
Plunger - usually power driven through gears with two, three, or five cylinders.

Steam Pumps

The most simple steam-driven, reciprocating pump consists of two cylinders on opposite ends of a pump rod. At the power end, steam moves the piston back and forth, which moves the piston in the liquid-end cylinder, correspondingly. Generally, this device pumps at both ends of the liquid cylinder.

With one cylinder, the device is known as a single - or simplex - steam pump.

For larger volume and smoother flow, two such single pumps are constructed as a unit, with the two steam cylinders and the two liquid cylinders synchronized. This arrangement is known as a duplex steam pump.

When describing a reciprocating steam pump, the diameter of the steam cylinder is given first, followed by the diameter of the liquid cylinder, then the length of the stroke, all in inches. For example, "6 x 4 x 6 pump" has a steam cylinder diameter of 6 inches, a liquid cylinder diameter of 4 inches, and a stroke of 6 inches.

Plunger Pumps

A plunger pump may be used when a higher pressure is required. A plunger pump may be either simplex, duplex or driven (through gears) by a power source. The three- or five-cylinder types of plunger pumps give smoother flow characteristics, with less pulsations, than either a simplex or a duplex pump. Instead of pistons in this type of pump, plungers (closed cylinders) are used to force liquid out of the chambers. Packing is on the outside (where the plungers enter the pump cylinder), allowing greater facility in inspecting and maintaining the packing.

ROTARY PUMPS

Rotary pumps have two gear-like rotating elements. The gears, which mesh, are confined in a housing with close clearances. Fluid enters the pump casing, is captured in the gear teeth, and forced to the discharge side of the pump. Meshing of the gears, and close clearances around the housing, seal the suction from the discharge.

A rotary pump may be used in small-volume services such as

potable water, hydraulic control systems and engine lubrication. (Most internal combustion engines are equipped with rotary oil pumps.) Rotary pumps also are used extensively on transport trucks (for unloading condensates, fuel oils and other liquids). Generally, a rotary pump is relatively inexpensive, costing less than a centrifugal pump of comparable capacity; however, service life of a rotary pump is relatively short, especially if used in a liquid having no inherent lubricating qualities.

DETERMINATION OF MATERIALS FOR PUMPS

Structural features of the parts of a given pump play a definite role in the final selection of pump materials. Choices often can be based upon corrosion and abrasion factors, but often these factors may not limit structural requirements. Some parts may require very thin wall sections, thus a material such as cast iron is not suitable even though it may not corrode. Similarly, shaft sleeves require a high degree of polish and only materials capable of accepting such a finish can be used. Or, if structural design requires pressed-on (or shrunk-on) parts, the material selected for these parts must be capable of withstanding this process. For example, for a pump impeller normally shrunk onto its shaft, bronze cannot be used - in this application the choice is usually limited to cast iron or stainless steel.

PUMP CHARACTERISTIC CURVES

Every pump exhibits characteristic curves (Figure 16-1-1). Note that this provides 1500 gal/min at 87-foot head and 1200

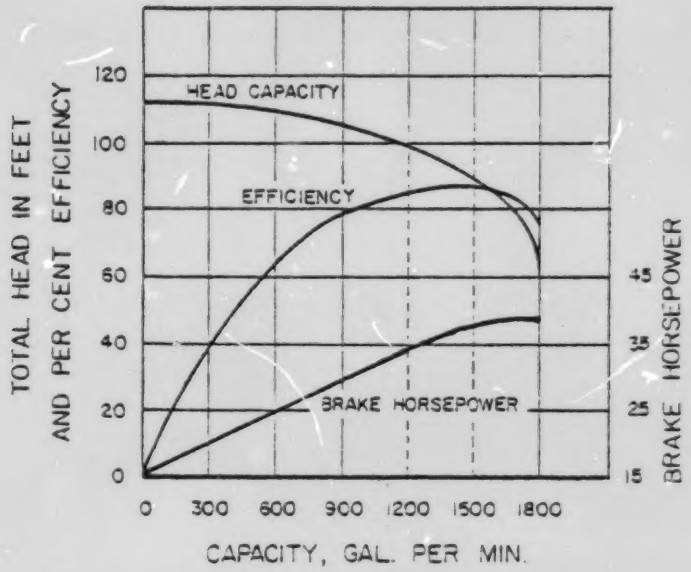


Figure 16-1-1. Characteristic curves for 8 inch, double-suction, centrifugal pump.

gal/min at 97-foot head at an efficiency of 85-percent in both instances. But, to drive the pump under the first set of conditions requires 37.5 horsepower, while the second condition only requires 35 horsepower. Beyond 1500 gal/min, efficiency drops off sharply, as does head capacity, but horsepower requirements remain essentially steady. The shapes of these curves vary somewhat for different designs and different sizes of pumps.

PUMP SPECIFICATION INITIATION

Data Tables 16-1-1, 16-1-2 and 16-1-3 (refer to DATA TABLES, pp. 15-17) are initial specification sheets (for

centrifugal pumps, reciprocating pumps and rotary pumps). Design engineers use such forms to inform interested manufacturers of pump specifications (e.g., configuration, materials, operating conditions, performance, and other details).

ENGINEERING, SCIENTIFIC AND TECHNICAL ORGANIZATIONS

Several professional organizations provide guidance to engineers, scientists and technicians by establishing standards for materials, construction, and performance characteristics.

The students should be familiar with technical library publications offered by these technical societies, especially those discussed below.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

The ASME, founded in 1880, is located at 345 E. 47th Street, New York, NY 10017. It lists a membership of more than 69,000 and maintains a staff of 150. This society conducts research, develops boiler and pressure vessel, and power test codes, serves as sponsor for the American National Standards Institute in developing safety codes and standards for equipment, maintains, with other engineering societies, a 180,000-volume library.

Divisions within the society include: Aerospace, Air Pollution Control, Applied Mechanics, Automatic Control, Bioengineering, Design Engineering, Diesel and Gas Engine Power, Energetics, Fluids Engineering, Fuels, Gas Turbine, Heat Transfer, Lubrication, Management, Materials, Materials Handling Engineering, Petroleum, Plant Engineering and Main-

tenance, Ocean Engineering, Power, Process Industries, Production Engineering, Rail Transportation, Safety, Solar Energy Applications, Solid Waste Processing, Technology and Society, Textile Engineering, Pressure Vessels and Piping, and Nuclear Engineering.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI, founded in 1918, is located at 1430 Broadway, New York, NY 10018. It has 1025 members, and a staff of 120. It works with industrial firms, trade associations, technical societies, consumer organizations, and government agencies. ANSI serves as a clearinghouse for nationally coordinated voluntary safety, engineering and industrial standards. It lends its status to projects developed by agreement in such areas as definitions, terminology, symbols and abbreviations, materials, performance characteristics, procedure and methods of rating, methods of testing and analysis, size, weight, volume and rating, practice, safety, health, and building construction. ANSI also provides information on foreign standards and represents U.S. interest in international standardization work.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM, founded in 1898, is located at 1916 Race Street, Philadelphia, PA 19103. It lists a membership of 24,000 and maintains a staff of 150. Engineers, scientists and skilled technicians hold memberships as individuals or as representatives of business firms, government agencies, educational institutions, and laboratories. ASTM establishes voluntary consensus standards for materials, products, sys-

tems and services. It has 120 technical committees (each having 5 to 50 subcommittees). New committees are organized each year to keep pace with technological advances. The society sponsors more than 125 research projects, and issues various awards for research and significant contributions in this area. ASTM has developed more than 5200 standard test methods, specifications and recommended practices now in use.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

This organization, founded in 1963, has the same address as the American Society of Mechanical Engineers. It has 170,000 members and a staff of 275. Membership includes engineers and scientists in electrical engineering, electronics and allied fields, and 16,000 students. Various boards within the institute deal with awards, conferences, educational activities, publications, regional activities, technical activities, groups, aerospace and electronic systems, antennas and propagation, audio and electroacoustics, broadcast and television receivers, broadcasting, circuit theory, communication technology, computer control systems and education, electrical insulation, electromagnetic compatibility, electron devices, engineering management, engineering in medicine and biology, engineering wiring and speech, geoscience electronics, industrial electronics and control instrumentation, industry and general applications, information theory, instrumentation and measurement, magnetics, microwave theory and techniques, nuclear science, power engineering, reliability, sonics and ultrasonics, systems of man and cybernetics, and vehicular communications.

AMERICAN NUCLEAR SOCIETY (ANS)

ANS, founded in 1954, is located at Oak and Catherine Streets, LaGrange Park, IL 60525. It has a membership of 12,000 and a staff of 60. Its membership is composed of physicists, chemists, mathematicians, life scientists, engineers, metallurgists and administrators with professional experience in nuclear science or nuclear engineering. The purposes of the society are 1) to advance science and engineering relating to the atomic nucleus, and allied sciences and arts and 2) to integrate the several disciplines constituting nuclear science and technology.

Local sections hold symposiums on technical subjects of national interest, such as fast reactor technology, nuclear power plant construction, licensing and startup, and aerial techniques for environmental monitoring.

Society divisions include: Controlled Nuclear Fusion, Education, Environmental Sciences, Isotopes and Radiation, Materials Science and Technology, Mathematics and Computation, Nuclear Criticality Safety, Nuclear Fuel Cycle, Nuclear Reactor Safety, Reactor Operations, Reactor Physics, Remote Systems Technology, and Shielding and Dosimetry.

AMERICAN SOCIETY FOR QUALITY CONTROL (ASQC)

ASQC, founded in 1946, is located at 161 W. Wisconsin Ave., Milwaukee, WI 53203. It has 23,000 members and a staff of 25. It is a society of professionals engaged in management, engineering and scientific aspects of quality and reliability. Through its Education and Training Institute, ASQC offers basic through advanced courses in quality engineering, managing for quality, management of quality

costs, auditing product quality, management of the inspection function, and applied statistics.

Divisions include: Administrative Applications, Aircraft and Missile, Automotive, Biomedical, Chemical, Electronics, Food, Drug and Cosmetic, Inspection, Reliability, Textile and Needle Trade, and Nuclear.

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (INDUSTRIAL EQUIPMENT)

This society, founded in 1924, is located at 1815 N. Fort Myer Dr., Arlington, VA 22209. It has 81 members and a staff of four. It is an engineering society for the valve and fittings industry devoted to standards, specifications and related engineering matters. It issues numerous publications on codes, standards and specifications.

Committees include: Ball and Butterfly Valves, Cast and Malleable Iron Fittings, Marking and Terminology, Pipe Hangers, Threaded and Solder Joint, Flanged Fittings and Valves, Steel Fittings, Unions and Union Fittings, Water Works, and Welding Fittings.

MATERIAL HANDLING EQUIPMENT DISTRIBUTORS ASSOCIATION (INDUSTRIAL EQUIPMENT)(MHEDA)

MHEDA, founded in 1955, is located at 104 Wilmot Road, Suite 208, Deerfield, IL 60015. It has 600 members and a staff of five. It works with manufacturers and distributors of material handling equipment and machinery.

Committees include: Business Finance, Education and Management Development, Manufacturers-Distributors Relations, Marketing, Performance, Safety and Standards, Service Operations and Systems and Products.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

1. From data provided by instructor, fill in the three pump specification sheets (Data Sheets 16-1-1, 16-1-2, and 16-1-3).

DATA TABLE 16-1-1
CENTRIFUGAL PUMPS

CUSTOMER			JOB NO.
PLANT			ITEM NO.
SERVICE			FILE NO.
NO. REQ.	MFG.	SIZE	P.O. NO.

OPERATING CONDITIONS

LIQUID _____ U.S. GPM AT PT, NOZ _____ DES _____
_____ DISCH PRESS., PSIG _____
PUMPING TEMP °F _____ SUCT PRESS., PSIG MAX _____ DES _____
SP GR AT PT _____ DIFF PRESS., PSI _____
VAPOR PRESS. AT PT. PSIA _____ DIFF HEAD, FT. _____
VISCOSITY AT PT. SSU _____ NPSH AVAIL. FT. _____
CORR/EROS CAUSED BY _____

CONSTRUCTION AND MATERIALS

CASING-MOUNTING (CENTERLINE) (FOOT) (BRACKET) (VERTICAL)
SPLIT (AXIAL) (RADIAL)
TYPE (SINGLE VOLUTE) (DOUBLE VOLUTE) (DIFFUSER)
TAPPED OPENINGS (VENT) (DRAIN) (GAGE CONNS.)

NOZZLES	SIZE	ASA RATING	FACING	POSITION
SUCTION				
DISCHARGE				

IMPELLER DIAM DES _____ MAX _____ TYPE _____
BEARING DES. RADIAL _____ THRUST _____
COUPLING AND GUARD _____ BASE PLATE _____
PACKING _____
MECH SEAL _____ CLASS CODE _____ MFR _____
BEARING LUBR. _____

MATERIAL CODE - EXTERNAL CASING ____ INTERNAL PARTS ____

C—CAST IRON
B—BRONZE
S—STEEL
C—12-13% CHROME
A—ALLOY
H—HARDENED
F—FACED
X—

INTERNALS CODE	I	B	S	C	X
IMPELLER	I	B	S	C	
INNER CASE PARTS	I	B	S	C	
SLEEVE (PACKED)	Ch	Ch	Ar	Ar	
SLEEVE (SEAL)	C	C	C	C	
WEAR RINGS		B	Ch	Ch	
SHAFT	S	S	S	S	
LANTERN RING					
PACKING GLAND					

PERFORMANCE

PROPOSAL CURVE NO. _____
NPSH REQ'D (WATER), FT _____
NO. OF STAGES _____ RPM _____
DES EFF _____ % BHP _____
MAX BHP DES. IMP _____
MAX HEAD DES. IMP FT _____
MIN CONTINUOUS, GPM (BY MFR) _____
ROTATION FACING COUPLING END
WATER COOLING
BEARINGS _____
STUFF BOX _____
PEDESTAL _____
GLAND _____
SEAL COOLER _____
TOTAL WATER REQ'D, GPM _____

PACKING COOLING _____
FLUSHING _____
AUX PIPING _____
THROTTLE BUSHING WITH VENT & DRAIN

SHOP TESTS	REQUIRED	WITNESSED
RUNNING PERF		
NPSH		

HYDROSTATIC TEST _____ PSIG
MAX ALLOW WP _____ PSIG _____ °F
WEIGHTS: PUMP _____ BASE _____
MOTOR _____ TURBINE _____

MOTOR DRIVER BY _____ TURBINE DRIVER BY _____

ITEM NO. _____ MTD BY _____
HP _____ RPM _____ FRAME _____
MFR _____
TYPE _____ INSUL _____
ENC _____ TEMP RISE C _____
VOLTS/PHASE/CYCLES _____
BEARINGS _____ LUBE _____
FULL LOAD AMPS _____

ITEM NO. _____ MTD BY _____
HP _____ RPM _____ MTL _____
MFR AND TYPE _____
INLET STEAM, PSIG _____ TEMP F _____
EXHAUST _____
STEAM RATE, PL _____ #/BHP/HR
BEARINGS _____ LUBE _____

	Housing Size	ASA Rating	Facing	Position
Inlet				
Exhaust				

MFR FINAL DATA (AS BUILT)

ACTUAL IMPELLER DIAM _____
TEST CURVE NO. _____
OUTLINE DWG NO. _____
PUMP SECT. DWG NO. _____
SEAL DIAM DWG NO. _____
PUMP SERIAL NO. _____

API STD. 610 GOVERNS UNLESS OTHERWISE STATED _____
REMARKS: _____

DATA TABLE 16-1-2
RECRPROCATING PUMP

CUSTOMER		JOB NO.
PLANT		ITEM NO.
SERVICE		FILE NO.
NO. REQD.	MFG.	P. O. NO.

OPERATING CONDITIONS	
LIQUID	DIFFERENTIAL PRESS. (PSI)
PUMPING TEMP. (°F)	CAPACITY @ PT (GPM)
SPECIFIC GRAVITY @ 60°F @ FT	MAX. WORKING PRESS. @ 60°F
VISCOSITY SSU @ 60°F @ FT	STALLING PRESS. (PSIG)
VAPOR PRESSURE @ FT (PSIA)	NPSH AVAILABLE FT.
SUCTION PRESSURE (PSIG)	NPSH REQUIRED FT. (WATER)
DISCHARGE PRESSURE (PSIG)	RELIEF VALVE SETTING
PUMP DESIGN	
TYPE	DISPLACEMENT (GPM)
SIZE	BRAKE (HP) HYDRAULIC (HP)
VOLMETRIC EFF. %	LUBRICATOR TYPE SIZE
MECHANICAL EFF. %	PISTON SPEED @ RATING (FPM)
RPM @ RATING	TYPE OF STROKE ADJUSTMENT
RPM MAX. ALLOWABLE	PRESS. TO LIFT SUCTION VALVES
SUCTION VALVE NO. SIZE	DISCHARGE VALVE NO. SIZE
SUCTION VALVE AREA SQ. IN.)	DISCHARGE VALVE AREA SQ. IN.)
SUCTION VALVE VELOCITY @	DISCHARGE VALVE VELOCITY @
DESIGN TEMPERATURE	DESIGN PRESSURE (PSI)
GEAR RATIO:	
CONNECTIONS	
SUCTION SIZE: RATING: FACING:	DISCHARGE SIZE: RATING: FACING:
SUCTION MANIFOLD HEADER	DISCHARGE MANIFOLD HEADER
VENTS AND DRAINS	FLUSHING OR COOLING WATER CONN
MATERIALS	
STUFFING BOX	VALVES
CYLINDER	VALVE SEATS
CYLINDER LINER	VALVE CAGES
PISTON	VALVE SPRINGS
PISTON ROD	VALVE COVER & HEADS
PISTON PACKING	BOLTING
PISTON ROD PACKING GLANDS	ROD PLUNGER PACKING
DRIVER	
TYPE HP RPM	
VOLTS PHASE CYCLES	
BEARINGS LUBE LOAD AMPS	
ROTATION OF DRIVER	
TESTING	
PERFORMANCE TEST	
HYDROSTATIC TEST TEST PRESSURE PSIG	
INSPECTION	
REMARKS:	

DATA TABLE 16-1-3

ROTARY PUMPS

CUSTOMER			JOB NO.
PLANT			ITEM NO.
SERVICE			FILE NO.
NO. REQD.	MFG.	SIZE	P. O. NO.

OPERATING CONDITIONS		CONSTRUCTION AND MATERIALS			
SERVICE		CASING			
LIQUID		PACKING OR MECH SEAL			
CAPACITY - GPM		BASE PLATE			
DISCHARGE PRESSURE - PSIG		COUPLING			
SUCTION PRESSURE - PSIG		IMPELLER DIAM DESIGN		MAX.	
DIFFERENTIAL PRESS. - PSI		TAPPED OPENINGS: VENT		DRAIN	
PUMPING TEMPERATURE - °F		SUCTION SIZE	ASA RATING	FACING	
SPECIFIC GRAVITY @ °F		DISCHARGE SIZE	ASA RATING	FACING	
VISCOSITY @ °F SSU		BEARING TYPE	MAKE		
VAPOR PRESSURE @ °F - PSIA		BEARING SEAL			
PERFORMANCE		LUBRICATOR TYPE			
PUMP SPEED - RPM		LUBRICATOR CAPACITY			
CAPACITY @ PUMP RPM	GPM	COOLING WATER-CONN.			
BHP REQD @ DESIGN		CASING GASKET			
DESIGN EFFICIENCY	% BHP				
NPSH REQD. (WATER) FT.					
NPSH AVAILABLE FT.					
DIFFERENTIAL HEAD FT.					
MAXIMUM BHP					
ROTATION FACING DRIVE					
RELIEF VALVE SETTING					

TESTING	ACCESSORIES
HYDROSTATIC PSIG	
INSPECTION	
WITNESSED BY	

MOTOR DRIVER BY			TURBINE DRIVER BY				MFG FINAL DATA AS BUILT
ITEM NO	MFG BY		ITEM NO				ACTUAL IMPELLER DIAM
HP	RPM	FRAME	HP	RPM	MFG		
MFG			MFG & TYPE				TEST CURVE NO
TYPE		NEMA	INLET STEAM PSIG		TEMP °F		OUTLINE DWG NO
ENC	TEMP RISE °C		EXHAUST PSIG		TEMP °F		PUMP SECT DWG NO.
VOLTS/PHASE/CYCLE			STEAM RATE PER		LB/BHP/HR		SPECIAL DIAM DWG NO
BEARINGS	LUBE		BEARINGS		LUBE		
FULL LOAD AMPS			NOZZLES	SIZE	ASA RATING	FACING	PUMP SERIAL NO
			INLET				
			EXHAUST				

API STD 610 GOVERNS UNLESS OTHERWISE STATED

REMARKS:

REFERENCE MATERIALS

None.

1. List two basic types of mechanical pumps discussed in this module:

2. List three basic classifications of pumps discussed in this module:

3. Define:

   Simplex.

   Duplex.

   Plunger.

4. List the three pump characteristics shown on a pump characteristics curve:

5. Give the full name for each of the following acronyms:

ASME.

ANSI.

ASTM.

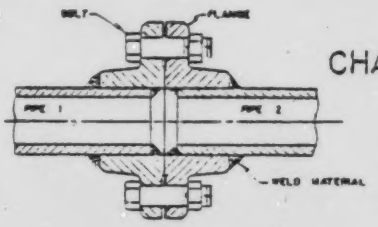
IEEE.

ANS.

ASQC.

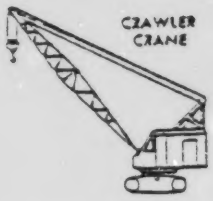
NUCLEAR TECHNOLOGY

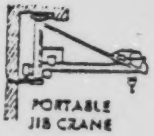
MODULE 16-2 PIPING CHARACTERISTICS AND SPECIFICATIONS

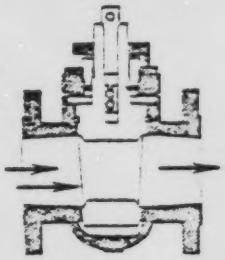


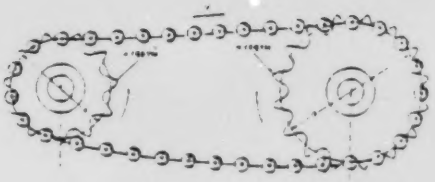
MECHANICAL COMPONENT
CHARACTERISTICS & SPECIFICATIONS

COURSE 16









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COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

MODULE 16-1	Pump Characteristics and Specifications
MODULE 16-2	Piping Characteristics and Specifications
MODULE 16-3	Valve Characteristics and Specifications
MODULE 16-4	Fastener Characteristics and Specifications
MODULE 16-5	Lifting and Handling Equipment Characteristics and Specifications
MODULE 16-6	Rotating Equipment Characteristics and Specifications
MODULE 16-7	Heat Exchanger Characteristics and Specifications
MODULE 16-8	Pressure Vessel Characteristics and Specifications

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INTRODUCTION

Pipes transport gases, liquids, and even finely ground solids in slurry. Pipe structure is simple: no matter what it's length, diameter, or shape, not matter what material it is made of, a pipe is a hollow cylinder, or tube. It is a system for containing, controlling and directing fluid flow.

Piping systems designed for power plant applications offer inexpensive, safe, and fast fluid transport (within such facilities, or into or out of them). Every kind of gas or liquid used in large quantities is moved in this way. Types of gases include oxygen, nitrogen, carbon dioxide, helium, natural and manufactured gas, steam and air. Liquids include water, chemicals and petroleum products.

Each material used in making pipe is selected for specific properties; the end use determines the properties needed. Rustproof cast iron has long been used for drain and sewer pipe, while steel pipe is used to transport gas and liquids that do not react chemically with it. Stain-steel pipe is the choice for use in chemical pipe systems and reactor coolant steam cycle systems.

Plastic pipe uses have increased steadily as plastic development has progressed. Plastic is light and flexible and some of the newer products are less affected by heat, sunlight, air and common chemicals than are some metal pipes.

To complete a pipe system, pipes must be joined by fittings; it must go around corners; and it must be joined to tanks, drains, pumps, valves, and other fixtures. In some instances, a system must change direction; in others, it must divide or branch. Small pipes can sometimes be bent to make a fit, but most must be joined with fittings. Generally, these fittings are made of the same material as the pipes.

Some fittings are attached to pipes by threads, some by flanges, some by clamps and others by welds; a few smaller ones may be soldered, glued or "packed."

Steel pipe and fittings usually utilize threads; large steel pipes more often are welded to one another or to fittings.

Plastic pipes and fittings maybe threaded, or they may be welded together by coating both ends with a solvent that melts together the surface of the plastic. As the two ends are fitted in place, the soft surfaces flow into each other to form a bond. When the solvent dries, the plastic hardens and the bond becomes permanent.

MODULE PREREQUISITES

The student should have completed Module 10-6, "Valves and Piping."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Demonstrate how pipe is joined, and explain why each type of joining method is used.
2. List specifications, codes and standards that apply to piping.

3. Given appropriate specifications and piping schedules, choose (from various catalogs) piping and joining system to fabricate a given system.
4. Given a specification requirement, test pipe sections to determine which best meets that requirement.

PIPE CLASSIFICATION

Steel piping is classified according to its method of fabrication.

BUTT-WELDED PIPE

Butt-welded pipe (Figure 16-2-1) is made in sizes up to three inches in diameter.* It is formed by long, narrow flat plates drawn through a die at welding temperatures, which butt-welds the edges of the plate by heat and pressure. Butt-welded pipe is used for low-pressure steam, water, and gas lines - but may not be used for temperature exceeding 450°F. This class of pipe is not suitable for flanging or close coiling.

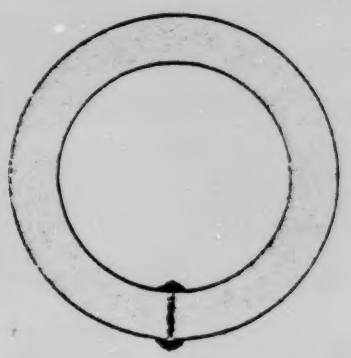


Figure 16-2-1.
Butt-weld pipe seam.

* "Pipe diameter," unless otherwise specified, indicates inside dimensions.

LAP-WELDED PIPE

Lap-welded pipe (Figure 16-2-2), in sizes up to 12 inches in diameter, has both edges beveled and formed with overlapping edges rolled between an internal mandrel and outside rollers at welding temperatures.

Figure 16-2-2.
Lap-weld pipe seam.

SEAMLESS PIPE

As the name implies, seamless pipe has no seam. It is made by piercing hot, solid cylindrical billets of steel, rotated between revolving rolls. By subsequent rolling operations, the seamless steel cylinder is formed into pipe of the desired dimensions and weight. Seamless pipe sizes up to 24-inches in diameter are common.

ELECTRIC-RESISTANCE WELDED STEEL PIPE

Electric-resistance welded steel pipe is made with a longitudinal welded seam. Steel plate, while still cold, is shaped into the required cylindrical form by means of a series of rolls. It is then fed into a welding machine where the edges are fused, the pipe is sized and finished. Lengths up to 50 feet are manufacturered readily with this process.

ELECTRIC-FUSION WELDED PIPE

Electric-fusion welded pipe can be used to manufacture large size segments. Steel plate is rolled, then welded longitudinally.

SPIRAL-WELDED PIPE

Spiral-welded pipe (Figure 16-2-3) is made by winding steel strips into a spiral, then welding the edges, either with butt or lap welds. Usually made of lightweight metal, its wall thicknesses are specified in U.S. Standard Gage Numbers.

Figure 16-2-3. Spiral-welded pipe seam.

PIPE SCHEDULE NUMBERS

Pipe wall thicknesses are given in schedule numbers (Table 16-2-1). These designations replace a former method of specifying (standard, extra strong and double extra strong). Schedule 40 pipe is used most for low- and medium-pressure service. For higher pressures or temperatures or, in certain instances, to provide for extra corrosion allowance, schedule

80 pipe, may be used. Extra strong wall pipe and scheduled 80 pipe, up to 8-inch sizes, are dimensionally the same. Double extra strong wall pipe has no corresponding schedule number.

TABLE 16-2-1
PIPE SCHEDULE AND RELATED DATA

Size		Wall	Nominal	Weight	Schedule	Test Pressure	
Nominal	Outside Dia	Thickness	Weight/ft	Class	No.	Grade I	Grade II
in.	in.	in.	lb			psi	psi
1/8	0.405	0.068	0.24	std	40	2500	2500
		0.095	0.31	XS	80	2500	2500
1/4	0.540	0.088	0.42	std	40	2500	2500
		0.119	0.54	XS	80	2500	2500
3/8	0.675	0.091	0.57	std	40	2500	2500
		0.126	0.74	XS	80	2500	2500
1/2	0.840	0.109	0.85	std	40	2500	2500
		0.147	1.09	XS	80	2500	2500
		0.294	1.71	XXS	...	2500	2500
3/4	1.050	0.113	1.13	std	40	2500	2500
		0.154	1.47	XS	80	2500	2500
		0.308	2.44	XXS	...	2500	2500
1	1.315	0.133	1.68	std	40	2500	2500
		0.154	1.47	XS	80	2500	2500
		0.308	2.44	XXS	...	2500	2500
1 1/4	1.660	0.140	2.27	std	40	2500	2500
		0.191	3.00	XS	80	2500	2500
		0.382	3.21	XXS	...	2500	2500
1 1/2	1.900	0.145	2.72	std	40	2500	2500
		0.200	3.63	XS	80	2500	2500
		0.400	6.41	XXS	...	2500	2500
2	2.375	0.154	3.65	std	40	2500	2500
		0.218	5.02	XS	80	2500	2500
		0.344	7.46	...	160	2500	2500
		0.436	9.03	XXS	...	2500	2500
2 1/2	2.875	0.203	5.79	std	40	2500	2500
		0.276	7.66	XS	80	2500	2500
		0.375	10.01	...	160	2500	2500
		0.552	13.70	XXS	...	2500	2500
3	3.500	0.216	7.58	std	40	2500	2500
		0.300	10.25	XS	80	2500	2500
		0.438	14.32	...	160	2500	2500
		0.600	18.58	XXS	...	2500	2500
3 1/2	4.000	0.226	9.11	std	40	2400	2000
		0.318	12.51	XS	80	2900	2800
4	4.500	0.237	10.79	std	40	2200	1900
		0.337	14.98	XS	80	2900	2700
		0.438	19.00	...	120	2900	2900
		0.531	22.51	...	160	2900	2900
		0.674	27.54	XXS	...	2900	2900
*							

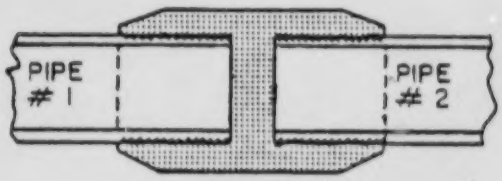
* Size of larger sizes - information is available from ASA B36.10 - 1959 Standards.

PIPE JOINTS

For connecting lengths of pipe and for installing valves and fittings in pipelines, some form of connecting joints is necessary. Threaded pipe joints are most widely used. For larger lines, welded joints, or flanges may be used. For two-inch lines, for example, flanged or welded or threaded joints may be used in a single system.

THREADED FITTINGS

Cast-iron, threaded fittings (Figure 16-2-4) are available in 150-pound standard and the 250-pound steam rating classes. These fittings are good for cold water, oil, gas and nonshock working pressures of 175 pounds and 400 pounds respectively.



THREADED
UNION

Figure 16-2-4.
Threaded union.

Malleable-iron fittings, threaded or welded (Figure 16-2-5), are used extensively. Because of the granular structure of malleable iron, fittings made of this material are capable of withstanding considerably more shock than ordinary gray iron castings. Malleable iron unions are used to make final connections in a run of threaded pipe. A ground-joint union, which depends for its seal on precise mating of two ground, beveled surfaces, is generally preferred.

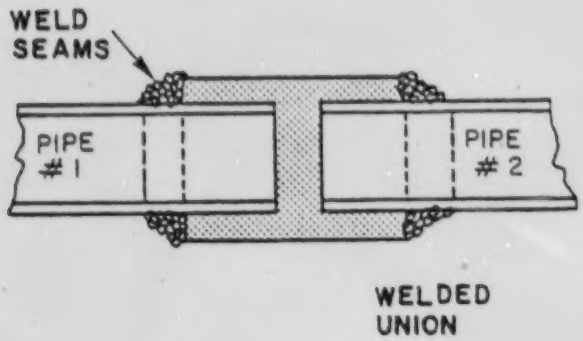


Figure 16-2-5.
Welded union.

For higher pressures and for hot oil lines, forged steel fittings are used. Forged steel unions, manufactured in the W.O.G. (water-oil-gas) series, are made for 2000 pound W.O.G., 3000 pound W.O.G., and 6000 pound W.O.G. (For steam, water, oil, oil vapor, gas or air, the nonshock, working pressures are as specified for 100°F; as temperature increases, working pressure decreases.)

FLANGED FITTINGS

The type of flange (Figure 16-2-6) most generally used is the welding neck flange. Slip-on flanges are sometimes used for special purposes, and threaded flanges are used infrequently.

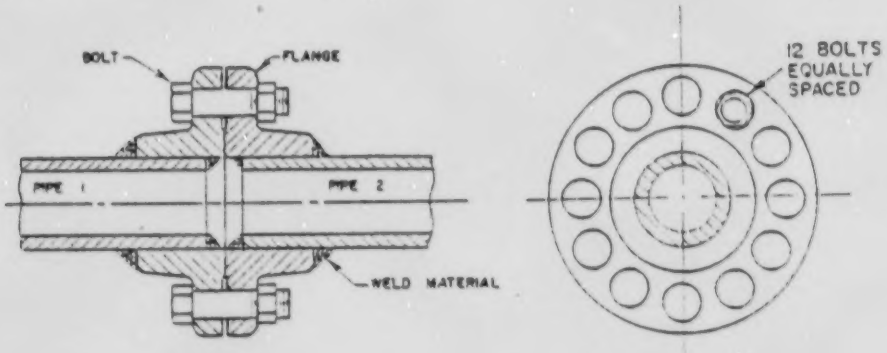


Figure 16-2-6. Bolted flange connection. (Note: Bolts encircle entire flange circumference.)

Cast iron is available but seldom used in a power plant because of breakage, both during installation and in service. Forged-steel companion flanges are manufactured in standard classes, including: 150 pounds, 300 pounds, 400 pounds, 600 pounds, 900 pounds, 1500 pounds, and 2500 pounds. Most companion flanges, especially in the 150- and 300-pound classes, incorporate a raised-face design.

One or more gaskets, made of asbestos-filled packing (or "composition") are used. Also, metal spacers may be used to ensure a snug fit. For high pressures or hot fluids, a ring-type insert may be used. Each companion flange face is provided with a circular groove into which a soft steel ring fits to form a tight joint. The purpose of the joint is to minimize the danger of blowout.

EXPANSION JOINTS

Four general types of elements used to compensate for pipe elongation - or contraction - caused by thermal expansion include:

Packless expansion joints.
Slip joints.
Swivel joints.
Inherent flexibility of pipe (through pipe bends, loops, right-angle turns, and so on).

PACKLESS EXPANSION JOINTS

Rubber corrugated copper, nickel steel, stainless steel, and other types of bellows may be used to fabricate packless expansion joints. Rubber should never be used where oil is present (oil rots rubber). Copper should not be used in superheated lines. Re-inforced copper often is used in moderate-pressure, saturated-steam lines and water lines. Also, it may be used with air and gases that do not affect copper. Expansion joints of nickel steel or stainless steel, made in several alloys, are used in superheated steam service, in bleeder lines from turbines, and in similar high-temperature services.

SLIP JOINTS

Slip joints are used frequently in water and saturated-steam lines at pressures below 125 pounds. (Occasionally this type joint is used in systems under pressures up to, or even above, 250 pounds). Slip joints also are used to a great extent in air, gas, and oil lines. They are made in a variety of patterns to fit the structural requirements of almost any application for whose pressure and temperature requirements they are suited. A principal disadvantage of slip joints is that they depend on packing and stuffing boxes for fluid tightness.

SWIVEL JOINTS

These joints, used extensively in steam, water-heating systems and, to some extent, other applications, are inexpensive and can be readily made up on the job from standard fit-

tings and pipe. An incidental disadvantage of such a joint is that it almost invariably introduces additional pressure drop because additional ells are required in its construction.

INHERENT FLEXIBILITY OF PIPE

It is general practice, in the case of high-pressure, high-temperature piping, to allow for thermal expansion through the elastic properties of steel pipe. Piping layout is planned to take advantage of directional changes (and incorporating joints) to provide the necessary flexibility. In instances where it is deemed impractical to install piping to obtain flexibility by directional changes, "expansion bends" may be inserted in the line (Figure 16-2-7). An example of such directional changes to achieve flexibility can be found in a power plant in the main steam piping from boiler to turbine where, frequently, two or more long runs of straight pipe are installed at right angles to one another without other expansion elements being used.

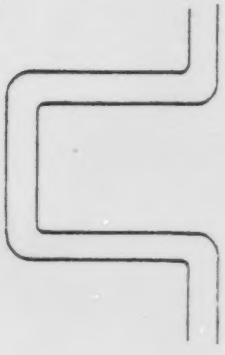


Figure 16-2-7.
Expansion bend in
pipe run.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

None.

DATA TABLE

None.

REFERENCE MATERIALS

None.

12

1. Sketch the following:

Butt-weld pipe seam.

Butt-weld pipe joint.

Lap-weld pipe seam.

Spiral-weld pipe seam.

Threaded pipe union.

Welded pipe union.

Flange pipe union.

Expansion bend (in a pipe run).

2. Pipe wall has thickness; from Table 16-2-1, provide the following data:

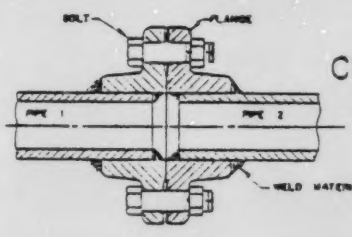
   Wall thickness in inches of 1/8" schedule 40 pipe.
   Outside diameter in inches of 1 1/2" schedule 80 pipe.
   Test pressure in psi of 4" schedule 60 grade I pipe.
   Schedule number of 2" pipe that weighs 7.46 lb/ft.

3. W.O.G. is an acronym; what does it stand for?

4. A forged steel pipe, W.O.G. 2000, can withstand _____ pounds of internal pressure at _____°F.

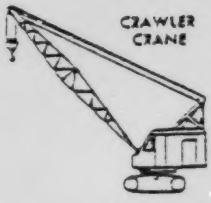
NUCLEAR TECHNOLOGY

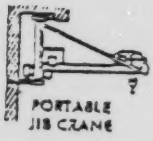
MODULE 16-3 VALVE CHARACTERISTICS AND SPECIFICATIONS

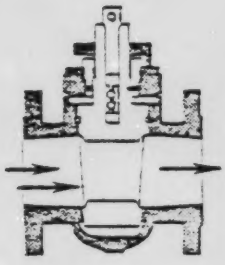


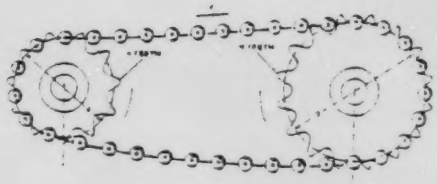
MECHANICAL COMPONENT
CHARACTERISTICS & SPECIFICATIONS

COURSE 16









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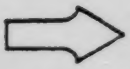
COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS



MODULE 16-1	Pump Characteristics and Specifications
MODULE 16-2	Piping Characteristics and Specifications
MODULE 16-3	Valve Characteristics and Specifications
MODULE 16-4	Fastener Characteristics and Specifications
MODULE 16-5	Lifting and Handling Equipment Characteristics and Specifications
MODULE 16-6	Rotating Equipment Characteristics and Specifications
MODULE 16-7	Heat Exchanger Characteristics and Specifications
MODULE 16-8	Pressure Vessel Characteristics and Specifications

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INTRODUCTION

Valves were described in considerable detail in Module 10-6, "Valves and Piping," including their applications relative to such environmental characteristics as pressures, temperatures, flow rates and contaminants. Their specifications and materials characteristics are given a general treatment in this module. Also, reference is made to specifying agencies and societies.

MODULE PREREQUISITES

The student should have completed Module 10-6, "Valves and Piping," and the previous modules in this Course.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. List four environmental characteristics of a valve.
2. Describe a typical valve, using terminology learned in Module 10-6 and this module.
3. Given a set of specifications, choose the valve that best meets the specifications.

4. Given performance requirements, test three valves to determine which best meets the requirements.

Valves regulate and control flow of fluids through piping systems and equipment.

The structural characteristics of a valve include a stem and yoke, packing (or packless construction), an angled flow or a straightaway flow, power or manual operation, and in some valves nonreturn or stop-flow arrangements.

Valves are constructed from a wide assortment of materials, and a wide variety of trim. Brass or bronze is used for general service valves; cast iron is used for low pressures (up to about 250 psi steam or 800 psi water). Steel and alloy steels are used for higher operating pressures and temperatures (e.g., 500 psi, 1200°F steam). Selected alloyed metals are used in the manufacture of valves utilized in chemical and process applications.

The majority of valves manufactured and marketed as off-the-shelf hardware items comply with requirements of the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI), and the American Society for Testing Materials (ASTM), insofar as material and dimension are concerned. (Note: These organizations are described in detail in Module 16-1, "Pump Characteristics and Specifications.") Construction techniques make available valves that are flanged, threaded, welded, sweated, or compression-fitted for connection to pipe, fittings and equipment.

A safety or relief valve provides predetermined or automatic relief for excessive pressure in a closed system. Such a valve, scrupulously specified, must open automatically when pressure exceeds a predetermined value; also, it must permit pressure to drop to a specified level before

closing to ensure safety and to avoid such irregular actions as chattering, instability and damage to valve and valve seat. Equipped with adjustment features for both relieving and blowdown, it must be tamperproof and safety-set by a responsible, licensed operator.

FUNCTION AND CHARACTERISTICS OF VALVES

The function of any valve may be described as follows:

To stop flow of fluid in a system. (Used for this purpose are gate valves, quick-opening valves and plug valves.)

To throttle or control quantity of flow. (Valves used for this purpose include globe valves, angle valves, needle valves, Y-valves, diaphragm valves and butterfly valves.)

To control flow direction. (Examples include swing check valves, lift check valves, ball check valves and nonreturn valves.)

GATE VALVES

A gate valve (Figure 16-3-1) is used primarily in a fully opened or fully closed position. It operates by raising or lowering a wedge, or disc, into the stream of flow. Manufactured in several different types, gate valves can be used for limited throttling service, but are not nearly as well adapted for this service as are globe valves. It is difficult to achieve fine throttling with a gate valve.

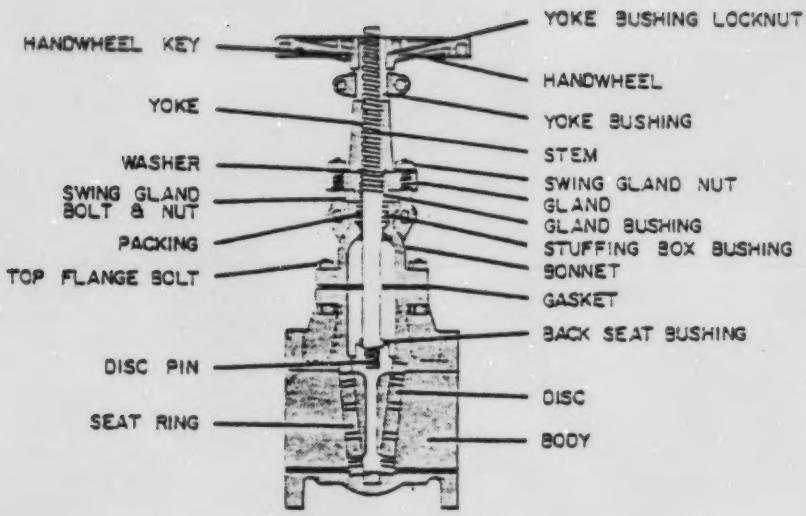


Figure 16-3-1. Typical gate valve, cutaway view.

Also, if used for throttling, the wedge gate within the valve may erode to the extent that the valve may not close to a tight position.

Wedges

A solid wedge, used most generally, is the most simple in design (fewer parts). It is less subject to chattering when the valve is partly opened because the wedge is closely guided through its travel.

A split wedge, or double disc, valve is used to secure more uniform distribution of pressure over the entire seating surface of the gate, thus compensating for any slight distortion of the valve body. A split-wedge valve is used primarily to control light, volatile liquids and gases that are difficult to contain.

A double-disc, parallel-seat, gate valve is equipped with two gates, or discs, and two bevel-faced wedges. When closing this valve, its discs are moved to their position opposite the seat rings by means of the upper wedge. Further

turning of the valve stem forces the wedges apart and secures them against the seat.

Stem

Gate valves are available with three types of stems:

Rising.
Nonrising.
Outside screw and yoke.

In a rising-stem valve, threads on the stem engage threads on the valve bonnet, which cause the stem and hand-wheel to raise or lower upon being turned. Rising stem valves are used when it is desirable for the operator to know at a glance whether the valve is in its open or closed position.

In a nonrising-stem valve, the screw on the stem, which raises and lowers the wedge, is inside the bonnet. This arrangement offers the advantage of needing a minimum amount of clearance for installation. Another advantage is that, in corrosive outside atmospheres, the threaded stem is less subject to damage.

An outside screw-and-yoke valve has its threads on the upper end of the stem completely outside the flow of material; this arrangement protects working parts of the valve from corrosive or eroding actions of fluid being handled. Also, the threads are easily reached for lubrication. But, most importantly, the exposed stem threads indicate on sight whether the valve is open or closed.

QUICK-OPENING GATE VALVES

A quick-opening gate valve is used when flow needs to

be stopped or started in a minimum of time. These valves are available in two major types:

Sliding-stem, with disc raised or lowered by hand lever.

Rotating-stem, with discs fastened to horizontal stem.

PLUG VALVES

A plug valve (Figure 16-3-2) is operated by turning a

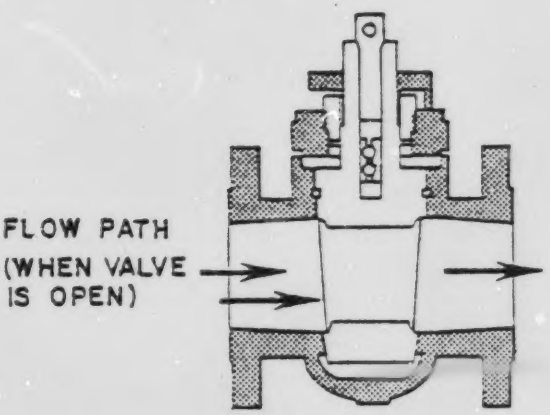


Figure 16-3-2.
Plug valve in closed position.

pierced plug (by means of a wrench, handle, gear mechanism or other device). This type valve is manufactured with either a lubricated or nonlubricated plug.

A lubricated plug is either tapered or cylindrical (tapered plugs are much more widely used). Sealing grooves, machined on the surface of the plug, provide channels for circulation of lubricant under pressure. The lubricant, usually a grease, keeps the plug in a freely working condition, seals against leakage, and protects adjoining sur-

faces from wear and corrosion.

A nonlubricated plug is used where contamination of the product is to be avoided. A solid-plug valve is loosened by a quarter turn of its handle (which lifts the plug). A split-plug valve, which is closed by mechanical expansion against the body of the valve after it has reached its desired position, contracts slightly when the mechanical pressure is released, allowing it to open with a minimum of friction.

GLOBE AND ANGLE VALVE

A globe (Figure 16-3-3) or angle (16-3-4) valve,is operated

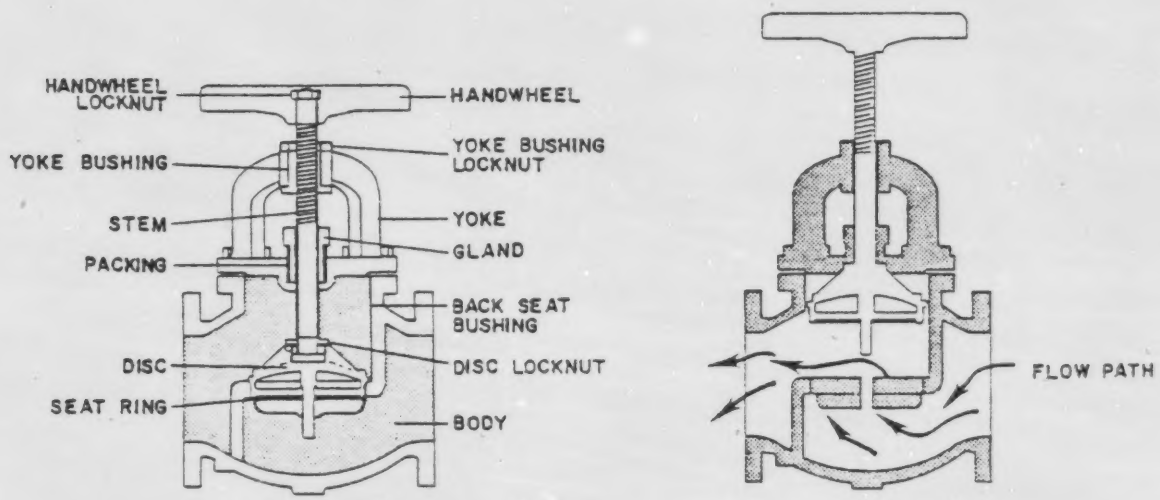
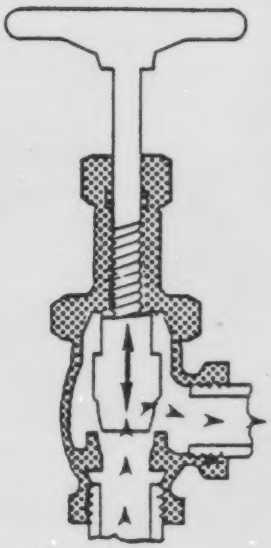


Figure 16-3-3. Globe valves, cutaway views showing (A) parts identification and (B) typical flow path.

by raising or lowering a plug, or disc, into a seat, which

Figure 16-3-4.
Angle valve, showing typical flow path.



divides the valve body into separate parts. A globe valve does not have the free-flow characteristics of a gate valve. Angle valves, which have slightly better flow characteristics than globe valves, are more compact and often less expensive.

A needle valve (Figure 16-3-5) (a type of globe valve made up in sizes up to one-inch) is used whenever close regulation of fluid flow is required. The lower end of the valve stem is precision beveled to fit into the valve seat.

CHECK VALVE

A check valve (Figure 16-3-6) permits fluid flow in only one direction. If a reversal of flow occurs, the valve closes automatically to prevent backflow in the line. There are four basic types of check valves, with selection depend-

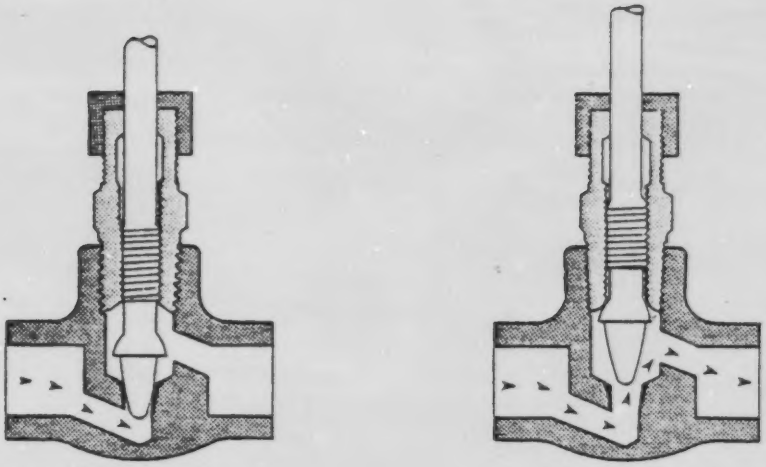


Figure 16-3-5. Needle valve, closed and open positions.

Figure 16-3-6. (A) Swing check valve, cutaway view; (B) horizontal lift check valve, cutaway view.

ing upon operating conditions and availability (all designs are not manufactured in all pressure-temperature ratings).

Swing Check Valve

Most commonly used because it is designed to cause the least resistance to flow, this valve is not recommended where frequent reversal of flow occurs - this action causes it to chatter.

Horizontal Lift Check Valve

Used where flow is irregular or subject to frequent reversal, this valve has a much lower tendency to "slam" in a fluctuating current.

Angle and Vertical Check Valve

Designed to be used in right-angle turns in piping, or in vertical lines flowing upward, this valve is a modification of the horizontal type.

Ball Check Valve

Made in horizontal, angle and vertical designs, these valves (Figure 16-3-7) are recommended for installation

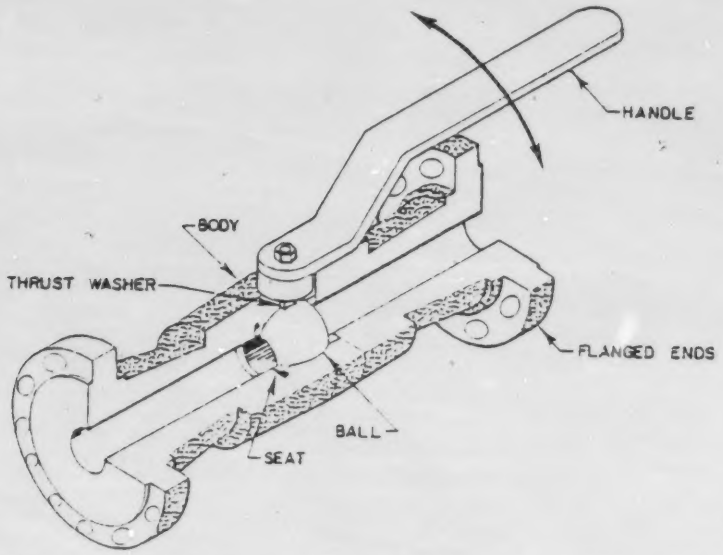


Figure 16-3-7. Ball valve, cutaway view.

in rapidly fluctuating lines because of their noiseless operation. Another desirable feature is that the ball tends to rotate during valve operation, which presents a contin-

ually changing surface to the valve seat, resulting in equalized wear.

CONTROL VALVE SPECIFICATIONS

Control valve specifications play an extremely important part in the design, fabrication and application of any control system. Standard control valve specification forms are often based on a standardized specification sheet for control valves (contained in the Instrument Society of America Recommended Practice RP 20.1, "Specification Forms for Instruments, Gages, Thermocouples, Orifice Plates and Flanges, Control Valves, and Pressure Safety Valves").

The following list of major items should be considered in any control valve specification form:

Body.
Actuator.
Positioner.
Transmitter or controller.
Service conditions.
Accessories.

EXERCISES

None.

MATERIALS

1 swing check valve (3/4").
1 angle check valve (3/4").
1 ball check valve (3/4").
2 pieces of 3/4" flexible water hose.
2 pieces of 3/4" iron, steel or plastic pipe with appropriate connectors (see Figure 16-3-8).
1 vat, tank or tub (approximately 10-gallon minimum capacity).

PROCEDURES

Use a laboratory system similar to that shown in Figure 16-3-8. Test three different check valves to see which provides the most desirable performance.

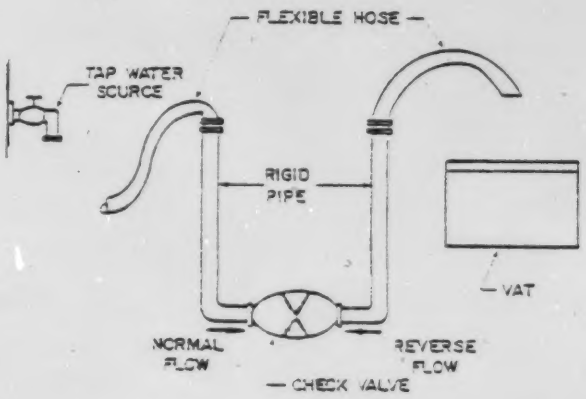


Figure 16-3-8. Typical laboratory setup for comparing check valve efficiencies.

1. Swing check valve:
   a. Install swing check valve in system.
   b. Connect system to tap water source for normal flow.
   c. Measure full flow for one minute; record flow on Data Table 16-3-1.
   d. Connect system to tap water source for reverse flow; open tap water source for full flow.
   e. Note the following: 1) does reverse flow cause valve to close automatically? 2) If valve closes, how long does it take? Use stopwatch. Record answers on Data Table 16-3-1.
2. Angle check valve:

   Repeat the above procedure with an angle check valve. Record data on Data Table 16-3-1.
3. Ball check valve:

   Repeat the above procedure with a ball check valve. Record data on Data Table 16-3-1.

DATA TABLE

DATA TABLE 16-3-1
CHECK VALVE COMPARISON

	Swing Check Valve	Angle Check Valve	Ball Check Valve
Normal Flow Rate (gal/min)			
Reverse Flow:			
Stopped Automatically (yes or no)			
Stopping Time (seconds)			

Which valve allows maximum flow rate? _____.

Which valve provides the quickest automatic reverse flow check? _____.

REFERENCE MATERIALS

The Crane Co. Flow of Fluids Through Valves, Fittings and Pipe. Technical Paper No. 410. Chicago: Crane Co., 1976.

TEST

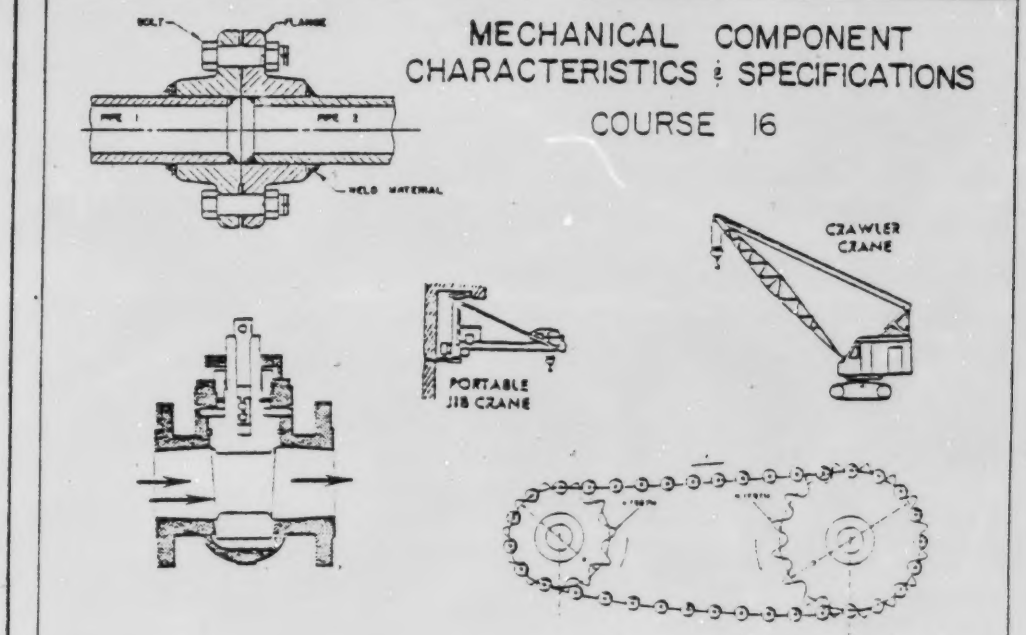
1. List four environmental characteristics that influence valve specifications:

2. Describe a typical gate valve; use terminology learned in Module 10-6 and reiterated in this module:

3. Given a set of specifications by instructor, state the type of valve that best meets the specifications:

NUCLEAR TECHNOLOGY

MODULE 16-4 FASTENER CHARACTERISTICS AND SPECIFICATIONS



TERC-SW

TECHNICAL EDUCATION RESEARCH CENTER — SOUTHWEST
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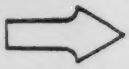
COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

MODULE 16-1 Pump Characteristics and Specifications

MODULE 16-2 Piping Characteristics and Specifications

MODULE 16-3 Valve Characteristics and Specifications



MODULE 16-4 Fastener Characteristics and Specifications

MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications

MODULE 16-6 Rotating Equipment Characteristics and Specifications

MODULE 16-7 Heat Exchanger Characteristics and Specifications

MODULE 16-8 Pressure Vessel Characteristics and Specifications

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INTRODUCTION

An essential basic in the technique of mass production is an understanding and knowledge of how to fasten or join parts together. Efficiency can be related directly to how fast and inexpensively parts can be assembled. Modern engineering additionally incorporates quick disassembly capabilities into many designs, for two reasons. First, in many instances, easy disassembly offers fewer maintenance problems when component replacement is required. Second, quick disassembly of support components enables extended use of major units (reusable parts and fasteners can be recycled).

Advances in fastener technology have brought a multitude of new designs, which makes it literally impossible to mention here any but the most standard fastening and joining techniques.

MODULE PREREQUISITES

None.

OBJECTIVES

Upon completion of this module, the student should be able to list and describe ten kinds of fastening used to join materials.

THREADED FASTENER

One of the most generally accepted methods of joining equipment and material is with threaded fasteners. Advantages of this technique include:

- Availability in wide ranges of size, style and materials.
- Capability for joining similar or dissimilar materials.
- Ease of installation, with use of manual or power tools, and with a high degree of safety.
- When subsequent maintenance or repair becomes necessary, threaded fasteners present relatively easy removal and replacement.

A standard threaded fastener system employs an internal (male) threaded element (such as a bolt or screw) and a mating external (female) threaded element (such as a nut, insert, or tapped hole).

Threaded fasteners are versatile in that they can be used for a single function, or in a combination of various functions. Low unit costs, standard threaded fasteners are available in various combinations of materials, strength levels, and finishes.

PRODUCT SPECIFICATION

Product specifications are basically manufacturing control documents identifying specific materials, finishes, methods of manufacture, heat treatments, strength levels and other information vital to proper fabrication. An im-

portant segment of product specification is the quality assurance provision, which defines test sampling(s) to confirm dimensional and performance objectives of the finished product. Product specification is a contract to ensure that the manufacturer delivers a finished product made in accordance with specified quality standards.

DESIGN SPECIFICATION

Differing from product specification, the design specification is meant to ensure structural and performance integrity of a fastener. It outlines conditions for use of the fastener. Criteria are based on experience and anticipated conditions of application. These criteria often reflect structural philosophy, including allowable working loads or stress levels, factors of safety, optimum or recommended fastener series for particular applications, installation and tightening requirements, special considerations requiring attention to safety and possible servicing, repair or replacement.

STANDARD PRODUCTS AND SPECIFICATIONS

A variety of types of screw threads and pipe threads are available for use in this country and abroad. Screw threads are classified as Unified and American, Whitworth, British Association Standard, International Metric Standard, Buttress, Hose Coupling, Fire House Coupling, Electric Socket and Lamp Base, Self-Locking, and Power Transmitting.

Unified and American thread standards have been agreed upon by standardization committees representing Canada, the

United Kingdom, and the United States. These unified standards constitute the basic American standards (ASE = American Standard Engineering).

Requirements of the final product include dimensional tolerances, metallurgical control, and mechanical performance properties. Each of these characteristics should be considered important in its own right, and should also be considered essential to the quality of the finished fastener with regard to its functional use.

A few of the more significant product criteria that are usually referenced in specifications are described below.

Dimensions and permissible dimension tolerances are detailed on standard or product drawings. Close adherence to specified tolerance limits is the key to dimensional interchange in the standard uniform series of fasteners. The large numbers of fasteners normally associated with production lots permits sampling in accordance with acceptable quality levels (AQL's) established for both critical and noncritical dimensional characteristics.

Threads on fasteners are subject to inspection because they represent a special dimensional gaging requirement. Certain thread characteristics of concern to the manufacturer include major, minor, and pitch diameter tolerance, angle error, lead error and "drunken" threads. Details for thread gaging and proper use of gages are summarized in American National Standard ANSI B1.2-1974, Gages and Gaging for Unified Screw Threads.

Metallurgical requirements, as opposed to mechanical properties, are intended to control quality, uniformity, and possibly the method of manufacture of the fastener. Checks for discontinuities, internal defects, grain size

indicative of proper heat treatment, and possible detrimental effects (such as too much decarburization) can only be made by metallurgical inspection.

SPECIFICATION SOURCES

Sources for some of the prominent classes of specifications in present use include:

Federal Specifications
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

Handbook H28, National Bureau of Standards
Superintendent of Documents
Government Printing Office
Washington, DC 20025

Military Specifications
Naval Publications and Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120

ANSI Standards
American National Standards Institute
1430 Broadway
New York, NY 10018
or
American Society of Mechanical Engineers
345 E. 47th Street
New York, NY 10017

ASTM Specifications
American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

SAE Specifications
Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

IFI Documents
Industrial Fasteners Institute
1505 E. Ohio Building
Cleveland, OH 44114

NAS Specifications (National Aerospace Standards Committee)
National Standards Association
1321 Fourteenth Street, N.W.
Washington, DC 20005

AMS Specifications (Aeronautical Materials Specifications)
Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

AAR Specifications
Association of American Railroads
59 E. Van Buren Street
Chicago, IL 60605

API Specifications
American Petroleum Institute
300 Corrigan Tower Building
Dallas, TX 75201

EEI Specifications
Edison Electric Institute
750 Third Avenue
New York, NY 10017

IOS Recommendations (International Organization for Standardization)
American National Standards Institute
1430 Broadway
New York, NY 10018

CORROSION

Corrosion is a concern in fastener design. The most common form, rust, affects steel fasteners. But all forms of corrosion must be compensated for in fastener design and fabrication.

NUT, BOLT AND SCREW

The task of classifying nuts, bolts and screws can be simplified if each type is considered on the basis of its function, form, thread or screw type and length. With this done, selection of the proper fastener can be resolved by checking a designated standard for critical dimensions.

Nuts, manufactured in many forms, are commercially available for almost any purpose or class of service. Nuts may be classified like many bolt heads in that some are intended to aid turning, and others are intended to resist turning.

Bolts are categorized as "regular" or "heavy." Regular bolts are intended for general use. Heavy bolts are for use where greater bearing surfaces are necessary.

Based on intended function, screws can be separated into the following categories:

Machine screws.
Cap screws.
Wood screws.
Tapping and set screws.
Special screws.

MATERIALS

Materials used in the manufacture of nuts, bolts and screws include: carbon and alloy steels, stainless steels, copper alloys, nickel alloys and aluminum.

LOCKING NUT, WASHER AND RETAINING RING

Through the years there have been a multitude of methods used to prevent loosening of nuts under vibration. Recently, lock nuts have been assigned to two different classes:

Nuts that lock themselves to the screw because of interference between internal and external threads.

Nuts that are free spinning until they engage a bearing surface, which causes the locking action.

Washers, placed under the heads of bolts and screws and under clamping nuts, distribute compressive stress over areas larger than that of the head or nut. They also serve as a means of preventing damage to finishes from the scraping effects of a head or nut as it is being tightened. Washers are also used between rotating parts to reduce wear on more expensive parts and to distribute thrust loads. Special forms of washers (called lock washers) perform the important function of preventing the loosening of associated screws, bolts and nuts.

Retaining rings are fastening devices used to provide shoulders for positioning or for limiting the movement of parts in an assembly. These rings usually are made of materials possessing good spring properties; thus, a fastener may be deformed elastically to a considerable extent and still spring back to its original shape.

RIVETING

One of the more popular methods of fastening and joining is riveting because it is simple, dependable and inexpensive. Its advantages include:

Production rates are high.

Initial and maintenance equipment costs are low.

Either metallic or nonmetallic materials can be joined.

Dissimilar metals and assemblies having any number of parts with nonuniform thickness can be joined readily.

The fastener, because it is a cold-headed part, has the uniform grain structure and inherent strength of a forging.

Unskilled labor can be taught its use.

Rivet can be made of a variety of materials.

Rivet can be used as a fastener, a pivot, a cam follower, an electrical contact or another functional component.

Disadvantages associated with riveting include:

Once parts are fastened, they cannot be easily disassembled.

Tensile and fatigue strengths of joints made with split, tubular or semitubular rivets are much lower than bolted or welded assemblies.

Joints are not normally watertight or airtight.

Protruding rivet heads may be undesirable in certain assemblies.

Riveting, compared with threaded fastening, requires no additional work or supplementary parts such as lock washers, nuts, or safety wires. Compared with welded joints, riveted joints offer more consistently uniform results (with no

requirement for x-ray or other expensive methods of inspection).

Stated simply, riveting consists of inserting a metal pin through holes in two or more parts and forming over the ends of the metal pin so as to secure the parts firmly together.

Rivets may be driven in, in either a hot or cold condition, by hammering or peening, or by application of steady pressure or by squeezing.

Rivets for metals are generally classified by type (such as large, small, tubular, split, hollow and special) and by the materials from which they are made (such as iron, steel, stainless steel, aluminum, brass, copper and nickel silver). Rivets can also be classified by the purpose for which they are used.

WELDING

Welding with pressure is generally broken down into the following classifications:

Resistance welding (includes spot, seam, projection, flash, upset and percussion welding).

Pressure gas welding.

Forge welding.

Stud welding (classified by the American Welding Society as an arc welding process).

Pressure thermit welding.

Cold or pressure welding (joining of metals by forcing two cleaned pieces together under pressure).

Hammer welding is used in the manufacture of heavy equipment such as steam boilers. Roll welding is commonly limited to the cladding of steel. Die welding is widely used in the fabrication of pipe.

A welding procedure that produces quality welds at the lowest possible cost would be considered an ideal procedure. There are many factors in almost every situation that influence a welding condition, making it most impractical to write procedures for each set of conditions. When trying to select a procedure, it would be best to study conditions of the welding task, then choose the procedure most nearly fitted to the conditions.

Ideal welding procedures produce quality joints and easily meet the requirements of commonly used codes. Welds that fit code quality requirements are intended to be defect-free to the extent that they measure up to the nondestructive testing requirements normally imposed by these codes. Testing requirements carry the implication that joints be crack-free, pressure tight, and with little or no porosity or undercut.

The Nuclear Regulatory Commission imposes stringent quality control on all welds within a nuclear reactor facility, and requires that welders employed in such a facility be certified to effect welds that meet the Commission's minimun requirements.

A standard called the "Five P's" ensures weld quality:

Process selection - process must be right for job.

Preparation - joint configuration must be right and compatible with welding process.

Procedure - to ensure uniform results, procedures must be spelled out in detail and followed precisely.

Pretesting - by full scale mockups or simulated speci-

mens, process and procedure are proved to give desired standard of quality.

Personnel - qualified people must be assigned to job.

ADHESIVE

Adhesives of very high strength have been developed for bonding metals, plastics, rubber, paper or combinations of these to other materials with an efficiency equal to other joining techniques, and often at a lower cost. These adhesives may be used to permanently join any material except those with wax-like surfaces (such as polyethylene, Teflon and Kel-F).

Adhesives offer definite advantages over other fastening methods. Generally, they are inconspicuous. They provide continuous contact between mating surfaces, which distributes load evenly over a joined area, eliminating local stress concentrations. Also an adhesive can seal against leakage of gases, dust or liquids. Adhesive bonds can be made resistant to salt spray, humidity and low temperature cracking.

The joining of different metals is often a source of galvanic corrosion, particularly with aluminum and magnesium. Such corrosive action is prevented in a bonded joint because the adhesive separates the metal. Such a bond, usually neoprene-phenolic or vinyl-phenolic resin, also can serve as an electric insulator.

COLLAR

A collar takes the place of a machined shoulder to provide a surface for holding other parts on a shaft. A collar can be held in place by a set screw, a taper pin, a straight pin riveted over, or an interference fit. A removable collar may be more suitable than a fixed collar or shoulder if the latter causes difficulty in assembling or dismantling the component onto the shaft.

SLEEVE

A sleeve may be appropriate on a shaft as a spacer or in lieu of a shoulder (turned as an integral part of the shaft). Also, a sleeve can be used as a coupling (one shaft to another) where light loads are to be transmitted. A compression sleeve is held in position by the wedging action of tapered members drawn together by nuts and bolts located parallel to the shaft axis.

A keyed sleeve generally is capable of transmitting fairly heavy torque loads. Normally, it is fastened to one shaft by means of a set screw, but transmits torque load through a key and keyway.

COUPLING

An ordinary rigid coupling is a simple device for fastening lengths of shafts, or pipes, together. Another simple device is the pipe coupling, which consists of a sleeve with internal pipe threads at each end. It can be made with or without external bands at the ends. (These couplings are also made to connect shafts and pipes of two different diameters.)

A screw coupling, which is similar to a pipe coupling, is also capable of transmitting torque loads. Internally threaded with a machine screw thread, it is provided with taper pins for each shaft to be joined.

A tapered coupling (a sleeve coupling requiring a tapered and threaded end on each of the shafts to be joined) is capable of transmitting somewhat larger torque loads.

A compression coupling (of the tapered sleeve type) consists of a double tapered sleeve. It is slotted from each end to be compressible against the shaft when the two flanged collars are drawn together by means of the associated nuts and bolts.

KEY AND SPLINE

Keys and splines are employed to prevent relative circumferential movement between rotating parts and the shafts on which they are assembled. They may or may not prevent longitudinal movement of such parts, depending on the type of key or spline used.

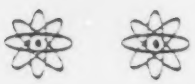
METAL STITCHING

A technique of stitching or stapling sheet metals with wire has been developed to the point that machines now available are capable of driving steel wire through 1/16-inch sheet metal at speeds up to 300 stitches per minute. This process, used to fasten metal to metal, or metal to a softer substance such as plastic, leather, rubber, plywood, fiberboard, sheet cork or asbestos, enhances strength and appearance.

Generally, metal stitching is suited to all joining operations ordinarily done with rivets, screws, cement or glue. It is difficult to compare strengths of steel stitches versus rivets or screws, but there is evidence that the stitches provide at least as much strength as some types of rivets.

EXERCISES

None.



MATERIALS

None.

PROCEDURES

None.

DATA TABLE

None.

REFERENCE MATERIALS

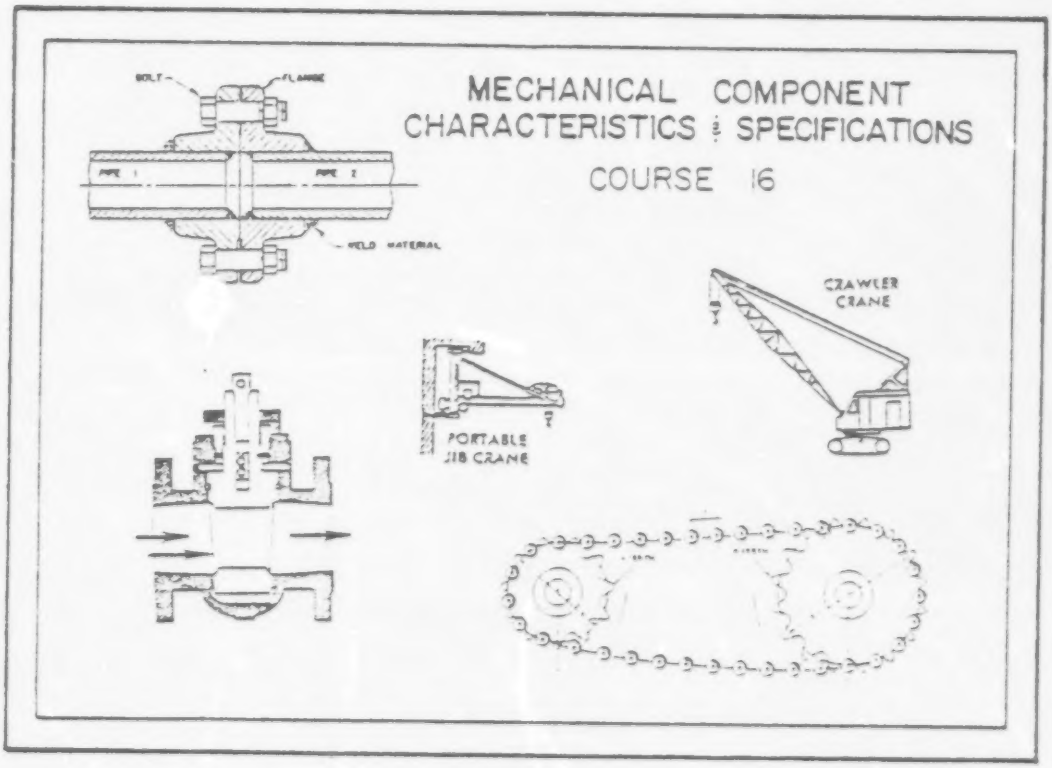
Laughner, Vallory H. and Hargan, Augustus D. Handbook of Fastening and Joining of Metal Parts. New York: McGraw-Hill Book Company, Inc., 1969.

Parmley, Robert O., ed. Standard Handbook of Fastening and Joining. New York: McGraw-Hill Book Company, Inc., 1973.

List and briefly describe ten of the eleven kinds of fastening systems described in this module:

NUCLEAR TECHNOLOGY

MODULE 16-5 LIFTING AND HANDLING EQUIPMENT CHARACTERISTICS AND SPECIFICATIONS



TERC-SW

TECHNICAL EDUCATION RESEARCH CENTER — SOUTHWEST
4201 LAKE SHORE DRIVE WACO, TEXAS

COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

MODULE 16-1 Pump Characteristics and Specifications
MODULE 16-2 Piping Characteristics and Specifications
MODULE 16-3 Valve Characteristics and Specifications
MODULE 16-4 Fastener Characteristics and Specifications
MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications
MODULE 16-6 Rotating Equipment Characteristics and Specifications
MODULE 16-7 Heat Exchanger Characteristics and Specifications
MODULE 16-8 Pressure Vessel Characteristics and Specifications

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INTRODUCTION

Lifting and handling equipment generally is designed to move materials swiftly, over a minimum distance in the safest manner possible. But characteristics of materials being moved most often determine the conveyance method used.

Equipment used may incorporate a mechanical, semimechanical, hydraulic, gravitational, pneumatic or electrical system, or a combination of two or more such systems. The International Materials Management Society has classified materials handling equipment (including lifting devices) as follows:

Conveyor.
Crane, elevator and hoist (including bridges).
Positioning, weighing and control.
Industrial vehicle.
Motor vehicle.
Railroad car.
Marine carrier.
Aircraft.
Container and support.

This module treats only the first three items as they are applicable to electrical power generating plants in general, and nuclear reactor plants in particular.

MODULE PREREQUISITES

None.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Describe at least two types of lifting units found in a nuclear facility and their operating principle.
2. Describe a materials handling unit and discuss why it is used in a nuclear facility.
3. List the more common types of lifting and handling equipment.

MATERIALS

In general, this discussion ignores conveyance by means of piping, tubing or similar enclosures. Materials handled in bulk form within a power plant include gases and liquids as well as solids, but these fluid materials must be confined in some kind of metal, glass or synthetic container. Solids, however, may range from finely ground coal dust to a multi-ton reactor vessel. Regardless of size, configuration or phase, all materials as well as equipment must be handled (moved).

CHARACTERISTICS

Characteristics of material to be handled determine handling equipment characteristics. Material characteristics include size, flowability, corrosiveness, abrasiveness, radioactivity and sensitivity to contamination, dampness, and the presence of dust or noxious fumes.

Materials characteristics are compiled and updated by manufacturers and trade associations. These trade associations publish technical bulletins relating machines to jobs, to product applications and to operating costs. Among these concerned organizations are the Power Crane and Shovel Association and the Conveyor Equipment Manufacturers Association. But useful data and specifications are published by various Governmental agencies and departments, in particular the U.S. Department of Commerce.

HANDLING SYSTEMS

Systems used to move bulk materials include:

Conveyors.
Cranes.
Elevators.
Trucks.

CONVEYORS

A conveyor system moves material continuously in a horizontal, vertical, or inclined direction along a predetermined path. Among the numerous types of conveyor systems are listed:

Gravity.
Apron.
Belt.
Skip hoist.
Bucket.
Dragline.
Flight (or screw).
Vibrating (or oscillating).
Pneumatic.

There are many variations of the belt conveyor with one notable difference being construction strength. More rugged requirements - for such items as coal and chemicals (as opposed to mail/package service) - may incorporate more exacting metallurgical specifications. Advantages of belt conveyors include low power requirements, high capacities, simplicity and dependable operation.

An apron conveyor (a series of metal aprons linked to form a continuous pattern) uses two strands of roller chain

that run on steel tracks, with movement provided by sprockets that lock into the chain links. Such a conveyor is well suited for moving heavy, lumpy or abrasive materials.

Gravity chutes, which are unpowered conveyors, have only a downward material movement capability. They incorporate such variations as steps or cleats used to slow movement of the material.

A series of buckets attached to a chain, or a belt, constitutes a bucket conveyor. This type of system, which works well on a steep incline or fully vertical path, is sometimes referred to as an elevator conveyor. The buckets, fabricated in a variety of shapes to accomodate a variety of applications usually are made of steel.

Flight conveyors (Figure 16-5-1) and dragline conveyors

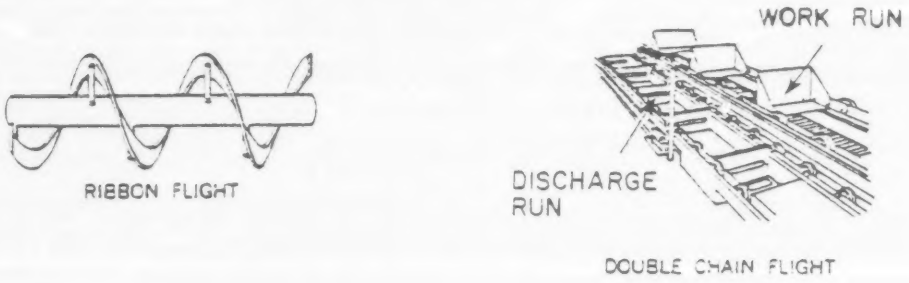


Figure 16-5-1. Flight conveyors.

operate on much the same principle. Bars drag or push material within an enclosed trough or duct by means of "flights." A spiral (or screw) conveyor (Figure 16-5-2) turns a shaft (which has flights attached in the form of a helical screw). The screw turns within a stationary trough, or casing, causing material to advance. Adding bars or paddles to a flight or conveyor shaft makes possible mix-

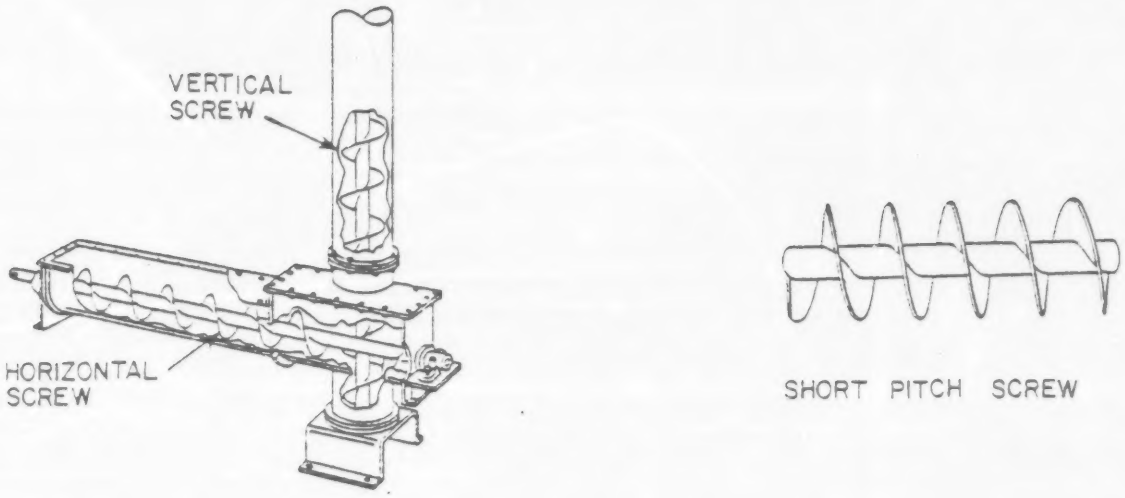


Figure 16-5-2. Typical screw conveyor.

ing or blending of materials as they are being moved.

A vibrator or oscillator attached to a conveyor keeps the load in a more advanced position on the carrying surface. (The vibrator or oscillator is designed to move forward slowly and draw back quickly to keep the material advanced.) These systems are used to handle hot, abrasive, stringy or irregularly shaped materials. The trough of such a system generally is enclosed to provide leakproof or dustproof conveyance.

Pneumatic conveyors use air to move materials. Small parts or packets may be propelled in such a system. A pneumatic conveyor may be a part of a larger conveyor system (a network that could be a combination of pneumatic, screw and vibrating conveyors).

ELEVATING MACHINES

Elevating machines, as opposed to hoisting machines, support their loads instead of carrying them suspended, and they travel a route that is both vertical and fixed. These materials-handling machines differ from vertical conveyors by operating with intermittent rather than continuous motion.

The three principal classes of elevating machines include:

Industrial lifts.
Freight elevators.
Stackers.

Industrial Lifts

Industrial lifts are used to raise or lower loads between the ground and the beds of carriers (used where no loading platform exists). They are also used as a form of platform in plants where a difference of elevation exists between floor levels of adjacent buildings. An industrial lift may be mechanically, hydraulically, or electrically operated.

Freight Elevators

Freight elevator design and construction provides for more rugged handling than that provided for passenger units because their platforms are often subjected to extra static loading, off-balance loading, and loading forces greater than passenger weights-area. Industrial elevators can be those set up temporarily on construction sites for moving material and personnel, or the more permanent installations found in factories and warehouses.

Some freight-handling elevators, built for special purposes, incorporate features such as platforms or arms for carrying specific material.

Stackers

A stacker is a tiering machine, or a portable elevator that stacks materials. Basically, a stacker has a pair of forks, or some other form of lifting device, vertical frames that support and guide the carriage, and a platform. The carriage can be raised and lowered by hand, by an electrically driven winch, or by a hydraulic cylinder. Newer models are powered by storage batteries or by small gasoline engines, which makes them more flexible in that they are not restricted in movement by the limits of a cord plugged into an electrical source. Stackers are equipped with floor locks (on their casters), which bolt into position during elevating or lowering operations.

INDUSTRIAL TRUCK

These trucks may be manually propelled or auto powered. They are used to transport materials over level, slightly inclined, or slightly declined surfaces. A common feature of industrial trucks is that all maintain contact with the running surface over which they operate and, with few exceptions, travel varying paths as opposed to fixed paths.

Manually operated industrial trucks include dollies, two-wheel trucks, multiwheel platforms and many more that fall into the broad category called "special."

Powered trucks include the nonlift platform type used to carry small loads or serve as shop tractors, and the powered low-lift skid truck or the high-lift fork truck.

MONORAIL

The monorail is an overhead, normally horizontal, track system made up of steel bars, galvanized pipes or standard I-beams. The wheels of the traveling trolley are held by the bars, pipes or beams.

The rails of the system are connected with butt, or lap, joints made smooth to allow the trolley to travel freely.

Spurs can be run into special work areas, and specially constructed sections permit 90-degree turns in trolley travel. Systems can be designed to run into freight elevators, along loading platforms, or directly into carriers.

Wheels are mounted on the trolleys and fitted to ride on the flanges of the track, with the number of wheels dependent upon the desired load carrying capacity.

Power to operate a monorail system is generally electricity.

CRANES

A crane is a hoisting machine used for handling materials in factories, warehouses, shipyards, and at construction sites. It moves heavy loads by means of ropes or cables positioned over pulleys.

The "jib" is a significant component of any crane (Figure 16-5-3). It is the horizontal or inclined load-bearing beam. Usually, it is equipped with structural supports to prevent bending. The jib supports either a movable pulley system that can travel a limited path, or a fixed pulley system. Ropes or cables used in the pulley system are wound onto a drum or cylinder that can be turned by hand

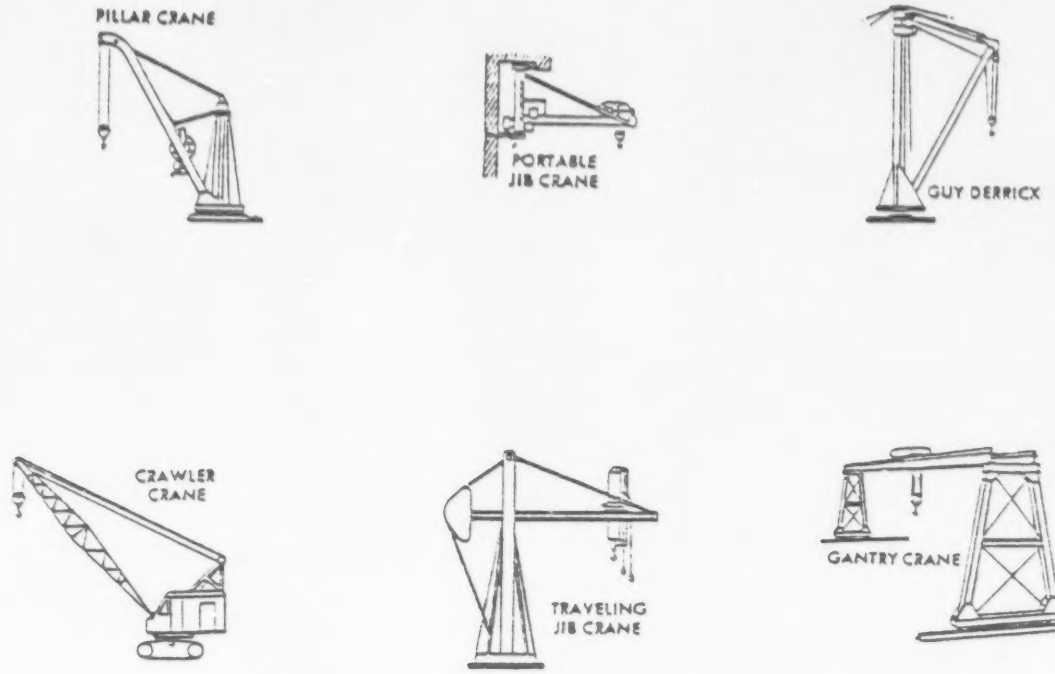


Figure 16-5-3. Types of cranes.

crank or a motor.

A variety of cranes are used for materials handling. Some are mounted on stationary supports while others are mounted on movable bases; some are classified by shape, some by the function they perform, and still others by their form of mobility. Then there are the special cranes that may be built with a variety of features.

Derrick Crane

A derrick is a special type crane on which distance from the end of the jib to the pillar can be varied. A guy derrick (Figure 16-5-3) has a pivoted pillar braced by guy ropes, and a jib that is attached to the base of the pillar. Inclination of the jib is controlled by a tackle that connects the top ends of the pillar to the jib. A hoisting

rope (or cable) extends from the end of the jib, over the top of the pillar, to the base of the pillar where it is connected to a drum.

A tower derrick differs from a guy derrick in that the tower jib is movable and can be secured at different heights of the pillar (or tower).

Pillar Crane

The pillar crane has a self-supported pillar, or column, that can be turned on its vertical axis. An inclining, or horizontal, jib is attached to the pillar and the load is raised or lowered from the end of the jib.

Portable Jib Crane

This type of crane is especially useful in various areas of shops and warehouses. It is small and can be attached to a column or wall of a building by means of adaptors or brackets that can be positioned at desired locations.

Cantilever Crane

This crane, with its jib extending outward from a supporting column that generally cannot be rotated, usually must provide counterbalance for its jib. The load is supported on one end of the jib, and a movable counterweight is supported by the jib on the opposite side of the column.

Traveling Cranes

There are several types of traveling cranes. One of the most common is the traveling jib crane. It has a pulley system suspended from a trolley that moves the length of the horizontal jib.

A gantry crane is one especially designed for outdoor use or where an overhead runway is not practical. It rests on a bridge supported at both ends by vertical columns or legs. These legs are mounted on wheels or rollers so that the entire structure can move on rails or tracks.

A traveling bridge crane has two elevated tracks bridged by a girder that travels along tracks on wheels. The hoisting unit can be moved back and forth along the girder bridge.

Truck Crane

This type of crane is mounted on a truck that moves on large wheels or on caterpillar treads (called a crawler crane). Truck cranes are versatile because they are self-propelled and can be fitted with accessory jibs, or booms, that extend to approximately 150 feet. Locomotive cranes, much like truck cranes, are designed to travel on standard gage railroad tracks.

Floating Crane

A floating crane is designed to hoist and transport cargo on and off ships at dock. Such cranes, mounted on pontoons or barges, also may be used for work on water.

MATERIAL HANDLING EQUIPMENT IN REACTOR PLANTS

Standard equipment must be modified for the process of handling materials, or specialized equipment may be designed. Criticality must be considered in choosing or designing material handling equipment, transporting containers, and the like, when fissionable material is handled. Equipment could be exposed to radiation or contamination and

should be suitably shielded and fabricated for ease in decontamination and maintenance. Cranes and other materials-transporting equipment must be constructed to rigid safety specifications to preclude any accidental release of material.

FUEL-HANDLING SYSTEM

A nuclear power plant fuel-handling system (Figure 16-5-4) is designed to perform all handling operations under water. During a fuel-handling operation, the system

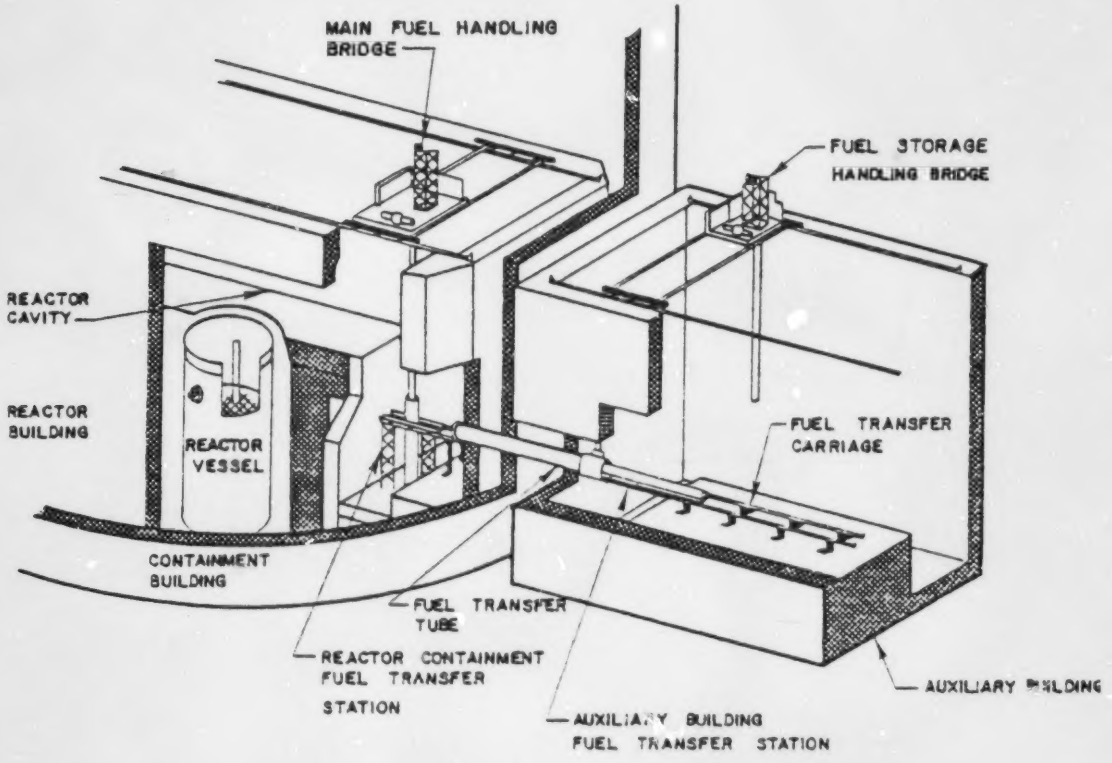


Figure 16-5-4. Fuel-handling system.

provides for the following:

- Transferring of spent fuel assemblies from reactor vessel to fuel-storage pool.
- Relocation of partially spent fuel assemblies from one station within the core to another.
- Transfer of new fuel assemblies from storage area into core.
- Handling of control rods, axial power-shaping rods, burnable poison rods and orifice rod assemblies, as required, to place these control components in their proper location in reactor core.

Reactor Cavity and Refueling Canal

The reactor vessel is located in a well, called a "reactor cavity," in the reactor building. The reactor cavity, an integral part of the reactor building, is constructed of reinforced concrete and lined with stainless steel.

During normal operations, the cavity houses reactor, reactor head and service structure. During refueling operations, a seal is placed between reactor vessel flange and cavity wall. The cavity, which is filled with borated water to provide radiation shielding and cooling for the irradiated fuel, is then called the "refueling canal."

The refueling canal provides storage for upper components, which must be removed to expose fuel assemblies. These components are highly radioactive and must be shielded by water in the reactor cavity.

In preparation for fuel handling, reactor cavity is filled, and upper internal components are removed and set aside in reactor cavity; also, communication is established between reactor cavity and fuel storage area. During fuel-handling operations, fuel-handling equipment performs all

distinct sequential operations necessary to complete a fuel assembly removal and replacement (handling) cycle.

A spent fuel assembly is removed from the core and transported to a reactor containment fuel-transfer station by way of a main fuel-handling bridge. It is loaded into a fuel-transfer carriage, which will transport it through a fuel-transfer tube into an auxiliary building. Once a fuel assembly arrives at the auxiliary building fuel-transfer station, the bridge removes it from the carriage and takes it to a designated fuel-storage rack for deposit.

A new fuel assembly is transported from its designated storage rack location to its new location in the core in a reverse sequence.

When main fuel-handling bridge is not being used to transfer fuel assemblies to or from fuel-transfer station, it can be used to shuffle fuel assemblies within the core to equalize fuel burnup.

Installation of a second, or auxiliary, fuel-handling bridge within the reactor containment building allows fuel shuffling to take place during fuel transfer.

Main Fuel-Handling Bridge

The main fuel-handling bridge (Figure 16-5-5), situated in the reactor containment building, is equipped with a multiple-function mast (Figure 16-5-6) designed to handle fuel assemblies or control rods during fuel-handling operations. A multiple-function mast consists of a fixed outer mast, an inner mast, fuel- and control-rod grapples and systems for raising and lowering fuel assemblies and control rods.

The fixed outer mast houses (and provides guidance to ensure vertical alignment of) the inner mast assembly.

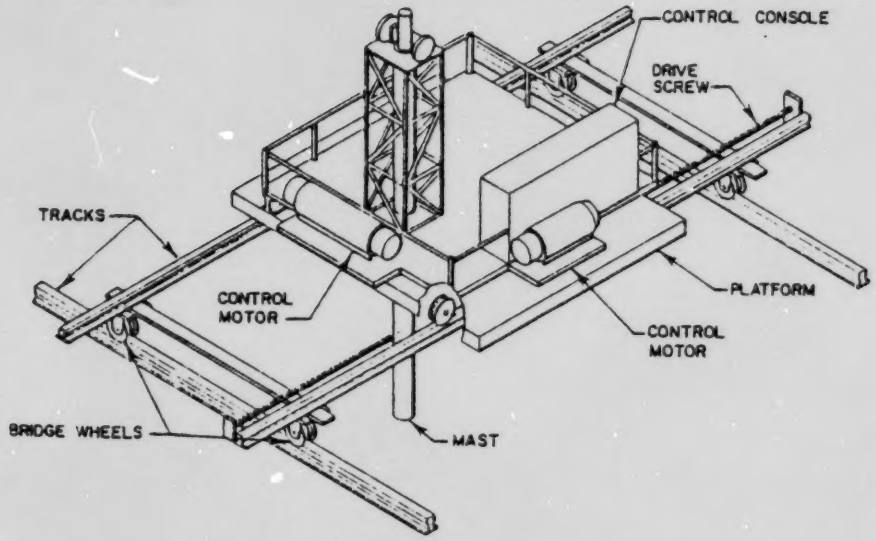


Figure 16-5-5. Main fuel-handling bridge.

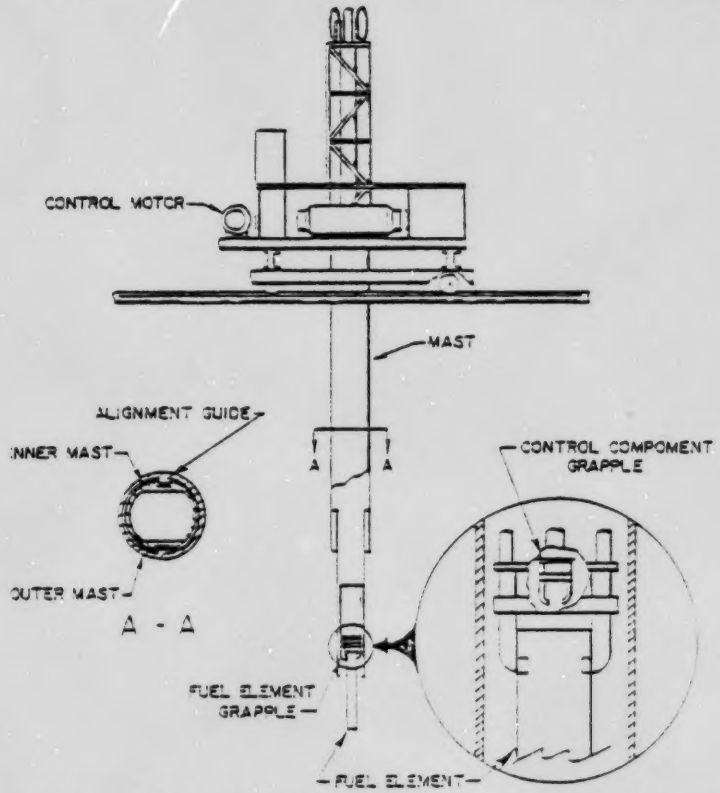


Figure 16-5-6. Main fuel-handling bridge with multiple-function mast.

During fuel-handling operations, when the inner mast assembly is at its up position and the fuel grapple is engaged with a fuel assembly, the fixed outer mast houses and protects fuel assemblies throughout bridge and trolley transport movements.

The inner mast assembly has a fuel-grapple assembly attached to its lower end; thus, it incorporates alignment guides to provide positioning of fuel grapple for engagement with fuel assembly. During vertical travel, vertical alignment is maintained by inner mast alignment guides situated in the fixed outer mast.

Also housed within the inner mast assembly are control-rod handling guides and control-rod grapple, which move up and down within the inner mast. Alignment of control-rod grapple with control component is accomplished by the grapple engaging the control component coupling. After engagement, the control-rod grapple is raised, withdrawing the control component from the fuel assembly, up through the disengaged fuel grapple until the control component is housed completely within the inner mast assembly. The inner mast assembly is then raised to its "up" position within the fixed outer mast.

One hoist, attached to the inner mast assembly via a mechanical linkage from the control-rod grapple, provides for all bridge raising and lowering functions. The hoist usually has two-speed circuitry. A slow-speed circuit is included as a safety feature to be used when inserting or withdrawing a fuel assembly or control component - the possibility exists of binding an element. During all other handling operations, hoist operation proceeds at maximum speed.

A hoist load-monitoring system continuously measures

and displays the loads supported by grapples. In this system are the limiting circuits for low-load, overload, fuel-grapple electrical interlock and underload. Hoist load circuit functions include:

Low-load (slack cable) circuit stops the hoist automatically in down direction when component being handled and its weight are no longer supported by grapple.

Overload circuit stops hoist automatically in up direction any time design load limit is exceeded. An excessive load is indicative of a stuck fuel assembly or control component.

Fuel-grapple electrical-interlock circuit prevents disengagement of grapple when it is supporting weight of handled component; to allow disengagement could result in dropping and damaging a fuel assembly or control component. Manual disengagement of fuel- or control-rod grapple is permitted only when element has been lowered into position and weight is no longer supported by grapple.

Underload circuit stops the hoist automatically in down direction when load being handled decreases below a preset limit. While lowering fuel assembly into position, circuit is in effect until approximately the last one inch of downward travel, at which time it is locked out of hoist control circuitry. Low-load circuit controls remaining downward hoist travel. (When underload circuit is locked out of hoist control circuitry, bottom guides of fuel assembly are engaged and guided by fuel-assembly supports in core and storage racks.)

Positive stops are located near upper end of outer mast assembly to prevent an irradiated fuel assembly or control component from being raised above the minimum permissible depth from pool surface.

An operator control console provides indicating lights and operating controls. The indicating lights, which provide operator with visual information about operational status of equipment, are color coded for ease of reference.

Bridge positioning is accomplished by visual observation of a precalibrated, selsyn-operated dial with hour and minute hand position readout. Trolley positioning is by visual observation of a pointer moving along a fixed scale with precision position markings. These components make up a position-indicating system, which is used to index bridge and trolley to their coordinate axes positions, with respect to the following:

Fuel-assembly core locations.
Transfer station.
Storage-rack locations.
Fuel and control-rod grapple test stations.
Failed-fuel detection container location.

This system is capable of positioning the center of the fuel or control-rod grapple within required tolerance above center of fuel assembly, or control component designated for handling.

Vertical position indication is provided by observation of a numbered tape attached to inner mast assembly. Two tapes are used to indicate multiple-function mast vertical position. One tape is attached to the inner mast assembly to indicate fuel assembly elevation, and another is attached to the control-rod grapple to indicate control-rod elevation. The tapes, mounted over the operator con-

trol console, provide a continuous display of elevation of component being handled.

In the event of a power failure, bridge, trolley and hoist functions can be carried on manually.

Fuel-Storage Handling Bridge

The fuel-storage handling bridge, situated in the fuel-storage building, has a single-function mast and operates over the spent-fuel storage pit. The fuel-storage handling bridge, identical to the main fuel-handling bridge, except that it is "single function," is not equipped to handle control components.

Fuel-Transfer System

The fuel-transfer system (Figure 16-5-7), used during refueling, transports fuel assemblies and control components

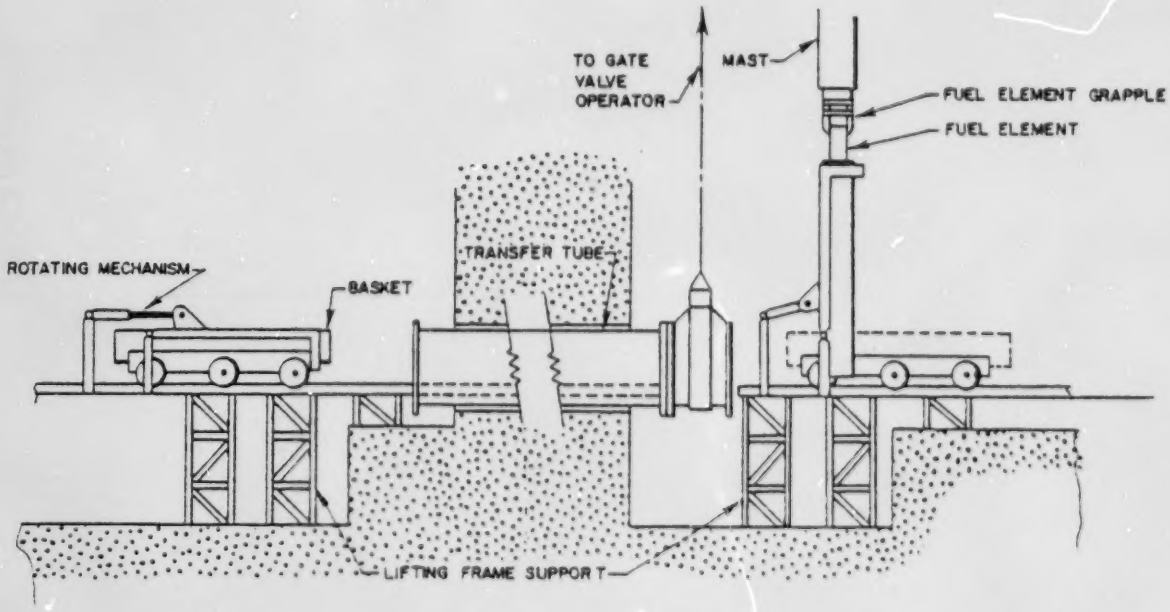


Figure 16-5-7. Fuel-transfer system.

between the auxiliary building and reactor containment building. It consists of the following components:

Two fuel-basket rotating frames.

One self-propelled carriage and fuel-basket assembly.

One fuel-transfer tube.

One manually operated gate valve, in the auxiliary building.

Two control consoles, in the reactor containment and auxiliary buildings, respectively.

During system operation, the self-propelled carriage and fuel-basket assembly approach a fuel-basket rotating frame; the fuel basket's "upending guides" engage rotating-frame lifting lugs. After the carriage travels to its end limit and stops, a hydraulic cylinder is actuated, which rotates the frame and engaged fuel basket to a vertical attitude. The fuel-handling bridge is then indexed over the vertical fuel basket for removal or insertion of a fuel assembly. All handling operations can be performed with or without a control component in the fuel assembly.

The self-propelled carriage and fuel-basket assembly, which has a permanently attached pullout cable, is powered by an underwater air motor. The motor's supply and exhaust hoses and emergency pullout cable are assembled on reels (in the auxiliary building). These reels are spring-motor driven and automatically unwind and retract as the carriage moves back and forth between containment and auxiliary buildings. Should an air-hose fail, the emergency pullout cable manually returns the carriage to the auxiliary building.

A control panel situated in the containment operates the fuel-basket rotating frame in the reactor containment; a control panel situated in the auxiliary building controls

the fuel-basket rotating frame in the auxiliary building and horizontal travel of the carriage. Carriage and rotating frames are interlocked to prevent inadvertent movement of the carriage when:

Fuel basket is in the vertical position.

Handling-bridge fuel or control-rod grapple are not at required preset positions.

Manually operated transfer-tube gate valve is not in full-open position.

A fuel-transfer tube serves as a passageway to transfer-fuel assemblies and control components, between reactor containment and auxiliary building. A gasketed cover plate, installed on reactor containment end of tube during reactor operation, is removed prior to flooding of reactor cavity. A manually operated gate valve, in the auxiliary building, is closed during reactor operation and opened during refueling.

Supplementary Equipment to Reduce Fuel-Handling Time

To decrease fuel-handling time, an auxiliary fuel-handling bridge and a second fuel-transfer system and fuel-transfer tube assembly may be installed.

Refuel Transfer Methods and Systems

New fuel is received on site in a shipping container. Each contains two fuel elements secured to strong backs in the container. Fuel is shipped in horizontal position. But, when container is opened, fuel is raised to a vertical position.

New fuel is stored dry until ready to be installed in reactor. It is removed from its shipping container, inspected

and placed in a new-fuel storage rack, designed to provide proper geometry to prevent criticality in the event of accidental flooding in the storage area. Additional protection is provided by oversize drains. Fuel remains in storage until it is transferred to the fuel-storage pool via elevator (Figure 16-5-8).

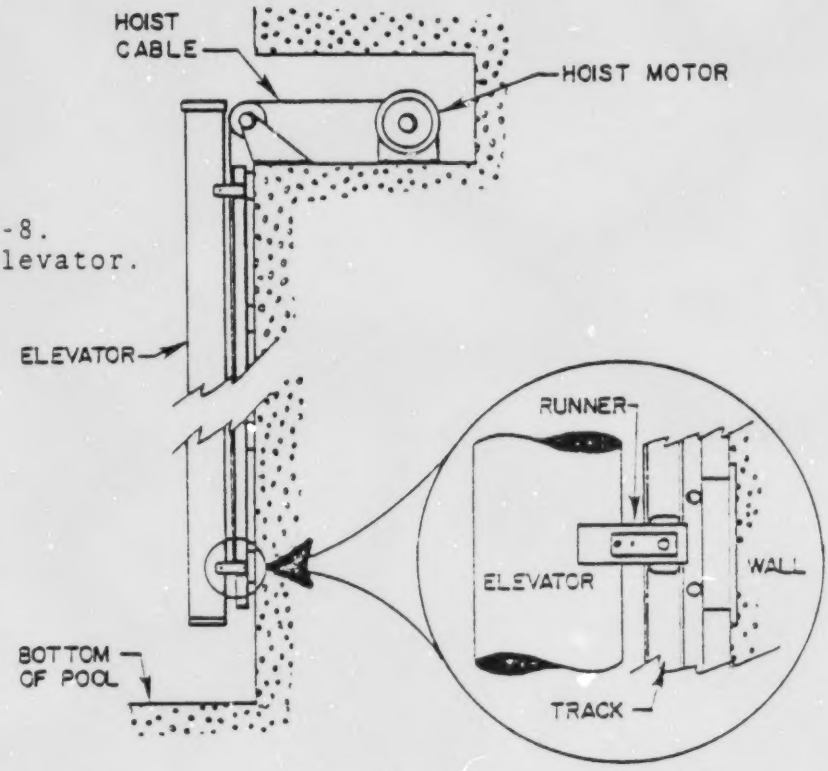


Figure 16-5-8.
Fuel-handling elevator.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

None.

DATA TABLE

None.

Harrer, J.M. Nuclear Power Reactor Systems Handbook. Vol. 1, USAEC Publication TID-25952-P1 (1973) and Vol. 2, USAEC Publication TID-25952-P2 (1974). Available by writing Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

Loftness, Robert L. Nuclear Power Plant Design, Operating Experience, and Economics. Princeton, NJ: Van Nostrand, 1964.

Masche, G.C. Systems Summary of a Westinghouse Pressurized Water Nuclear Power Plant. Pittsburgh: Westinghouse Electric Co., 1971

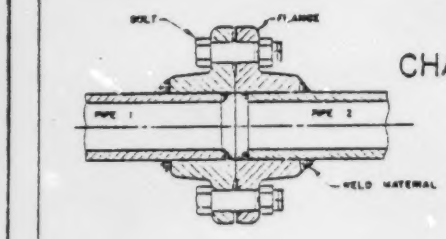
1. Describe a nuclear power plant main fuel-handling bridge (make a sketch if necessary):

2. Describe a nuclear power plant fuel-transfer system (make a sketch if necessary):

3. List the three more common types of lifting and handling equipment associated with a nuclear reactor system:

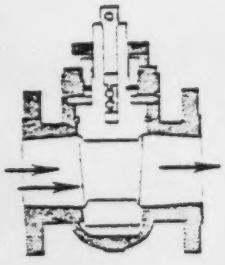
NUCLEAR TECHNOLOGY

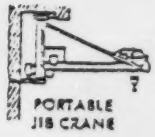
MODULE 16-6 ROTATING EQUIPMENT CHARACTERISTICS AND SPECIFICATIONS

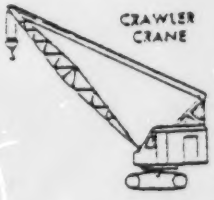


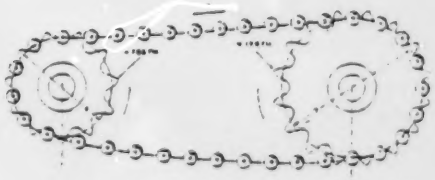
MECHANICAL COMPONENT CHARACTERISTICS & SPECIFICATIONS

COURSE 16









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TECHNICAL EDUCATION RESEARCH CENTER — SOUTHWEST
4201 LAKE SHORE DRIVE WACO, TEXAS

COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

MODULE 16-1 Pump Characteristics and Specifications
MODULE 16-2 Piping Characteristics and Specifications
MODULE 16-3 Valve Characteristics and Specifications
MODULE 16-4 Fastener Characteristics and Specifications
MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications
MODULE 16-6 Rotating Equipment Characteristics and Specifications
MODULE 16-7 Heat Exchanger Characteristics and Specifications
MODULE 16-8 Pressure Vessel Characteristics and Specifications

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INTRODUCTION

Characteristically, a steam turbine is subjected to enormous stresses of temperature, pressure, velocity and centrifugal force. When it comes to rest the counter-effect of these forces can cause various difficulties. To overcome such problems, the turbine shaft is rarely allowed to come to a full stop and is never allowed to remain at rest for an extended time. To maintain its movement when steam flow ceases, special rotating equipment is used.

This module describes such equipment in very general terms, and suggests the sources and rationale for rotating equipment specifications.

MODULE PREREQUISITES

The student should have completed Module 10-1, "Power Plant Fundamentals," and Module 10-3, "Turbines and Generators."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Describe two purposes of turbine shaft rotating equipment.
2. List and describe the four subsystems of a rotating equipment system.
3. Identify the turbine linkage mechanism by which the rotating equipment motivates the turbine shaft.
4. Describe a compound gear train.
5. List and describe by function the two automatic control mechanisms associated with rotating equipment.
6. Describe turbine shaft "jacking."
7. Define:
   - Shaft bowing.
   - Shaft warping.
   - Out-of-round.
8. Describe how shaft rotating affects lubrication.
9. List four items looked for during shaft inspection.
10. Identify source(s) of rotating equipment specifications.

Rotating equipment serves two purposes: it provides continuous rotation of the turbine shaft during shutdown, and it provides incremental jacking of the shaft for inspection and maintenance. A typical turning gear (Figure 16-6-1)

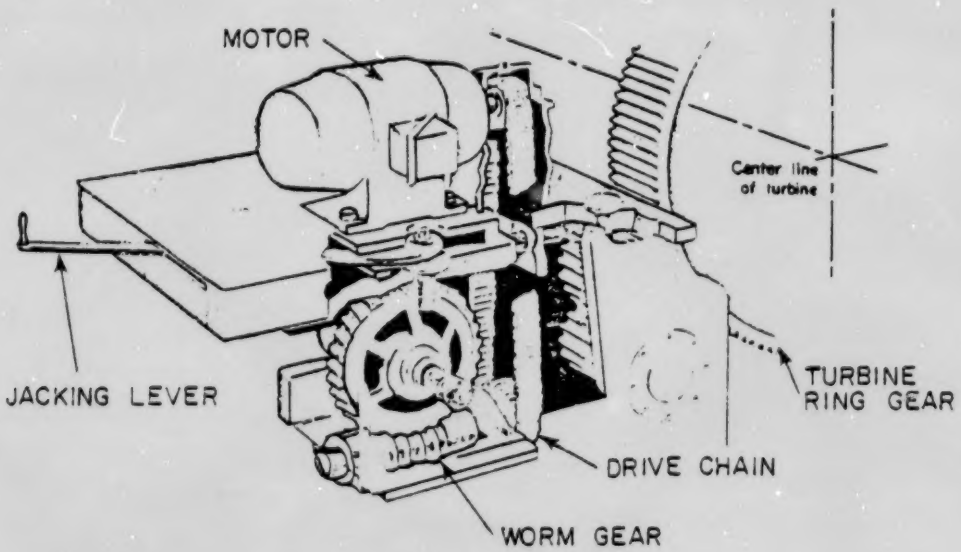


Figure 16-6-1. Side-mounted rotating equipment.

incorporates a power source, drive mechanism, a linkage mechanism and a mechanical or servo control mechanism.

A high-speed turbine of the size (Figure 16-6-2) and

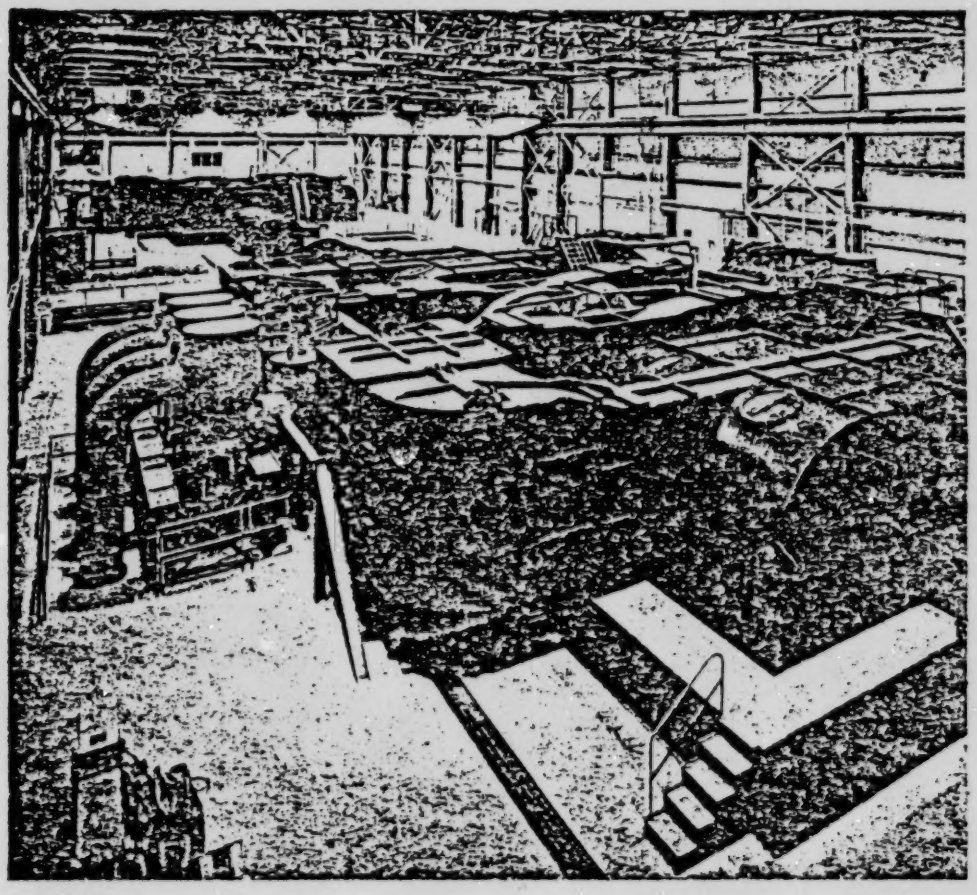


Figure 16-6-2. A typical nuclear power plant turbine generator.

productivity used in a typical electrical generating plant, though heavy, incorporates incredibly accurate balance with equally accurate bearing surfaces. Thus, when in motion, very little added energy is required to keep it rotating. Similarly, its dead-stop inertia is not excessively difficult to overcome (that is, it starts up rather easily from a dead stop). Frequently, then, as in the case of slow or incremental rotation for inspection, the rotating equipment retards shaft rotation by applying a braking action. The arrangement of gears - the drive mechanism - allows this control feature.

DRIVE MECHANISMS

> The ratio of input-to-output of a compound gear train (Figure 16-2-3) is equal to the product of tooth ratios of the simple trains included in the compound train.

This ratio is significant only in understanding the control capability that can be gained by a carefully designed gear ratio. And, because power plant turbines require braking, startup and jacking control, the student must appreciate the full array of characteristics associated with a specific rotating system. It is, after all, these characteristics that reflect specifications for the equipment.

A typical speed-reducing gear box (Figure 16-6-4) may consist of half a dozen or more gears, as opposed to the four shown in the complex chain-driven worm-and-gear arrangement in Figure 16-6-1. It should be noted that a chain

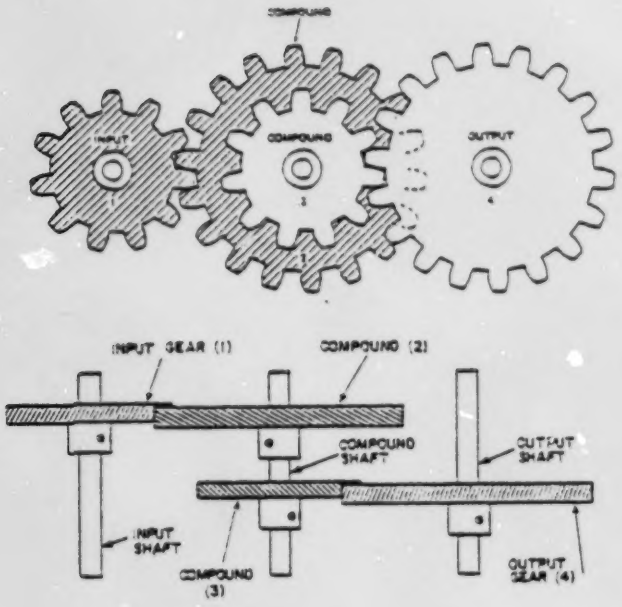


Figure 16-6-3. Compound gear train.

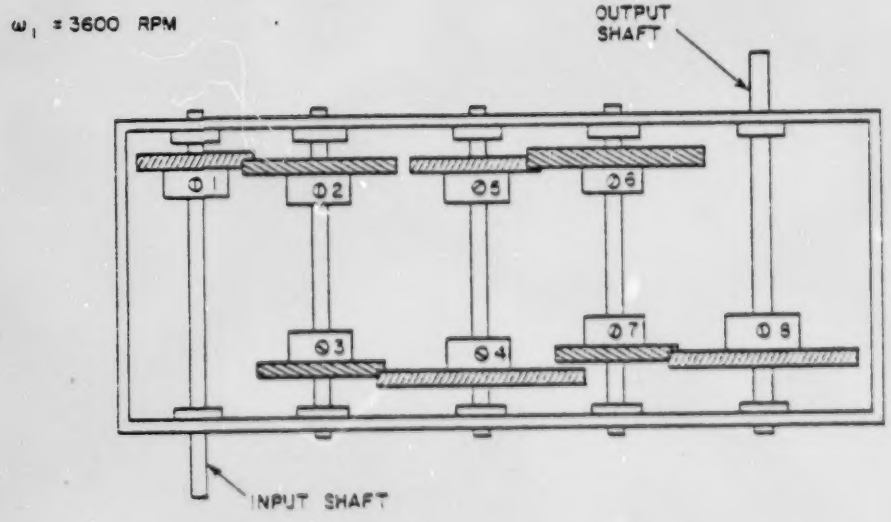


Figure 16-6-4. Typical speed-reducing gear box.

drive (Figure 16-6-5) links the energy source to the worm

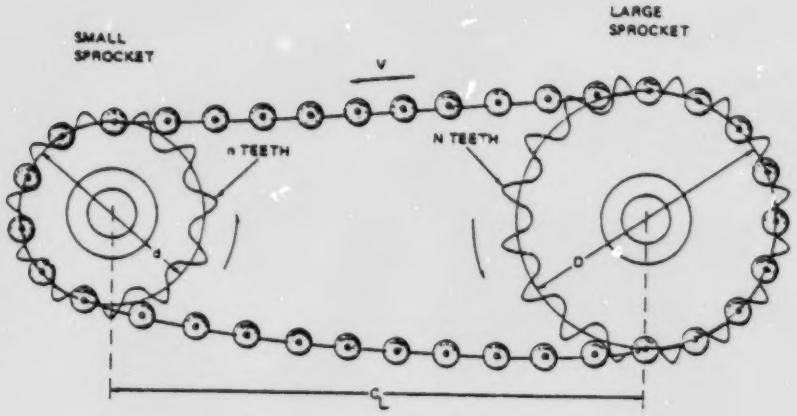


Figure 16-6-5. Typical chain drive.

gear. Chain drives are used in applications in which center distances are too large for economical gearing, and other linkage (such as belts) either allow slippage (which cannot be tolerated) or tend to lose reliability over extended periods of nonuse.

The equipment depicted in Figure 16-6-1 also employs a universal drive (Figure 16-6-6), though it is not shown.

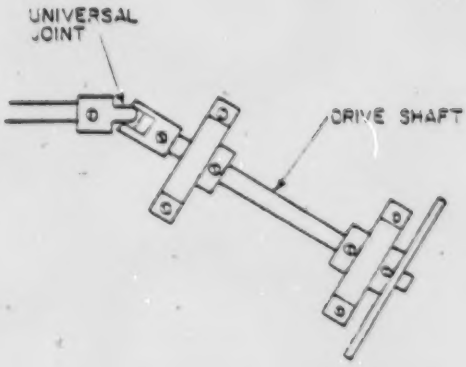


Figure 16-6-6.
A universal drive.

The energy source (in this case, a slow-rotation, high-torque electric motor) must be carefully suited to the application.

CONTROL MECHANISMS

Rotating equipment requires two automatic control mechanisms. One control system regulates shaft revolutions per time increment (e.g., r/min). The other system provides automatic engagement of the rotating equipment during a turbine shutdown, and automatic disengagement (at a predetermined r/min) during turbine startup.

Manual control (for full stops and/or incremental jacking) is provided by turning off or disengaging the energy source (electric motor) for the rotating equipment, which allows the turbine to "glide" to a full stop. Then incremental jacking is performed manually by moving a lever arm (Figure 16-6-1) back and forth. Each stroke of the lever rotates the turbine shaft approximately three degrees, or 1/120 turn. (Note: This ratio may vary according to equipment size, application and manufacturer, but must meet closely specified requirements.)

ROTATING EQUIPMENT FUNCTION

The rationale for not allowing a turbine shaft to be at rest for an extended time is twofold.

SHAFT BOWING

As noted previously, a steam turbine in service is subjected to high temperatures. Because the turbine is made of metals it is temperature sensitive, especially the turbine shaft, which consists of metal material of considerable bulk. As this metal cools (as in a shutdown), it does so unevenly - the center of the shaft cools more slowly than its outer surfaces; therefore, the shaft tends to bow and warp.

Also, at speed, the shaft is subjected to great centrifugal forces, which are alleviated as the turbine slows down. As a result, stresses on the shaft are significantly altered with changes in turbine speed.

Yet another factor is weight distribution: as the shaft slows, the enormous weight of the turbine becomes a greater factor in shaft configuration (bowing) and in bearing stress.

BEARING MAINTENANCE

The final consideration is lubrication. It is the rotation of the shaft in the bearings that distributes and maintains the lubricating film between the surface of the shaft and the bearing surfaces. If rotating ceases, lubrication ceases.

INSPECTION

A damaged, cracked, bowed or out-of-round shaft implies danger and commands down time for replacement or extensive maintenance. A bowed shaft destroys seal strips (at the

diaphragms, blading and rotor) and prohibits startup. Other "out-of-spec" conditions create equally significant problems. Thus, periodic inspections - preventive maintenance - are an integral part of any system's operating, technical specifications.

To conduct such an inspection, the turbine shaft is incrementally rotated, as described previously. Simultaneously, it is submitted to a variety of metallurgical tests, it is measured in every dimension while at rest, and it is examined visually (and with x-ray and fluoroscope, if necessary) for flaws.

Also, while being rotated at idle (shutdown) speed, it is "micked" (measured by micrometer) for out-of-round to calibrate the automated turbine eccentricity and vibration instrumentation.

SPECIFICATIONS

Specifications for rotating equipment are developed by turbine manufacturers to ensure proper shutdown, startup and maintenance of the turbine. (A typical turbine is expected to have a life of 40 years of operation if properly serviced and maintained.) Additionally, the turbine operator (utility company) may impose specifications on the equipment based on experience with similar equipment or special operating conditions or parameters of a specific plant.

SUMMARY

Turbine shaft rotating (jacking) equipment generally is a motor-driven system consisting of a combination of gears that mesh with a ring gear mounted on the turbine shaft, which - when engaged - turns the shaft at a very slow speed. It is usually attached on one of the turbine pedestals. The rotating equipment has two functions. It rotates the turbine shaft continuously during turbine start-up and after shutdown (when large temperature changes are occurring or have occurred) to prevent rotor bowing or warping. A bowed shaft prohibits turbine startup - it destroys seal strips at the blading, rotor and diaphragms. The turning gear is also used as a means of jacking the shaft in small increments for inspection or maintenance of shaft or turbine parts.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

1. From one or more vendor catalogs provided by instructor, compile a list of items specified for rotating equipment.
2. Visit a nearby power plant (it does not have to be nuclear fueled) and note size and general parameters of rotating equipment. Specifically, note size and type of energy source, and drive mechanism(s). Ask operator about maintenance schedule of turbine, and frequency of use of rotating equipment. Note its normal shutdown r/min, engagement r/min and disengagement r/min.

DATA TABLE

None.

REFERENCE MATERIALS

None.

1. Briefly describe two purposes of turbine rotating equipment:

2. List the subsystems of a rotating equipment system:

3. State purpose of a turbine shaft ring gear (as given in this module):

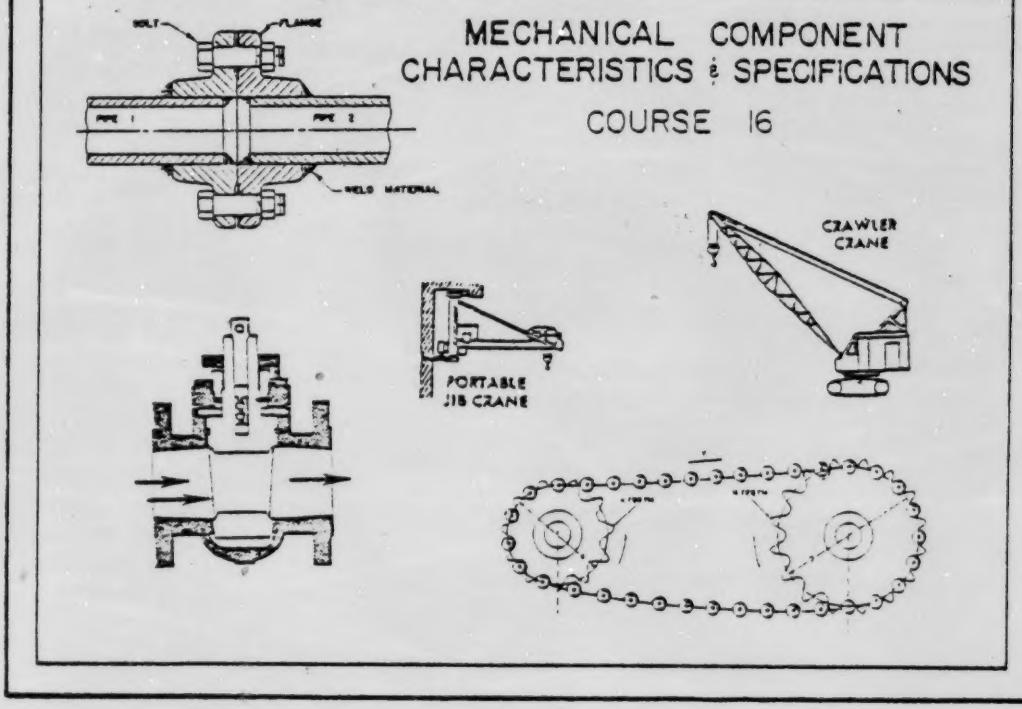
4. List and briefly describe the two automatic control mechanisms associated with a rotating equipment system:

5. Briefly describe the process called turbine shaft "jacking":

6. List two primary sources of rotating equipment specifications (as given in this module):

NUCLEAR TECHNOLOGY

MODULE 16-7 HEAT EXCHANGER CHARACTERISTICS AND SPECIFICATIONS



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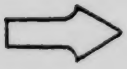
MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications

MODULE 16-6 Rotating Equipment Characteristics and Specifications



MODULE 16-7 Heat Exchanger Characteristics and Specifications

MODULE 16-8 Pressure Vessel Characteristics and Specifications

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INTRODUCTION

A heat exchanger is an engineered device used to transfer heat from a hot fluid to a cooler fluid. During this transfer, the hot fluid is cooled and the cooler fluid is heated, with none of the transferred heat being lost. The transfer device usually is a tube within a tube, with the fluids separated by the wall of the inner tube. The physical and mechanical characteristics of heat exchangers are described in this module.

MODULE PREREQUISITES

Student should have completed Module 10-4, "Heat Exchangers."

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Describe basic principles of heat transfer.
2. List and describe thermal and hydraulic characteristics of a heat exchanger.
3. List five classes of heat exchangers.

4. List three kinds of problems encountered in heat exchanger maintenance; state how these problems are resolved.
5. By using parameters and/or characteristics provided by instructor, write specifications for three different heat exchangers.

A heat exchanger can be designed to internally complete an energy generation process. That is, the exchanger, which becomes an integral part of the reaction system, may be known as a "reactor" (catalytic, polymeric or nuclear).

Normally, a heat exchanger only transfers, eliminates or recovers heat, with no accompanying phase change. The fluids on either side of the tube wall, or barrier, are usually liquid, but can be gases (such as steam, air or hydrocarbon vapors).

The barrier between the fluids generally is metal, but it can be graphite, plastic or some other corrosion-resistant material. Actually, a barrier is not an essential component of a heat exchanger - the fluids may simply intermingle.

Exchangers are used widely in the chemical processes industries, in the generation of steam for production of power and electricity, in nuclear reactor vessels, in aircraft and space vehicles, and in cryogenics for low-temperature separation of gases.

CLASSIFICATION

Shell-and-tube heat exchangers are most common, though they constitute but one of many types. Varying fluid passage arrangements and baffle-and-shell alignments contribute to a growing multiplicity of available designs; however, there are only five general classes:

Class 1. Heat exchangers with one fluid at a relatively constant temperature, which gives up heat to a colder fluid, the temperature of which gradually increases as it flows through the exchanger. The constant-temperature fluid may be at rest or flowing in any direction. Example: a power plant steam condenser.

Class 2. Heat exchangers with one fluid at a constant temperature, which receives its heat from a warmer fluid, the temperature of which decreases as it flows through the exchanger. Example: a power plant steam boiler.

Class 3. Parallel-flow heat exchangers with two fluids flowing in the same direction; both fluids change temperatures. Examples: water heaters, oil heaters and fluid coolers.

Class 4. Counterflow heat exchangers (two fluids flowing in opposite directions - the most popular class of fluid heaters and coolers.

Class 5. Cross-flow heat exchangers in which one fluid flows opposite another fluid. Example: tube banks in a superheater.

HEAT EXCHANGER DESIGN

Calculations play a necessary part in the design of heat exchangers. For example, in any heat exchanger design the engineer must predict its performance, including pressure drops, exit temperatures and heat transfer rates for

specified flow rates, inlet temperatures and pressures. Heat exchanger geometry varies with characteristics (flow rates, temperatures and pressures) of particular fluids, as well as with heat exchanger classification and application. Also, cost, weight and volume become significant variables. For example, design often is restricted by space limitations. Generally, however, space availability is not as critical in power plant design as are cost and other considerations.

New processing problems present new challenges to heat exchanger designers. Much emphasis has been placed on loading more heat-transfer surface into less and less volume. For example, extended surface exchangers, with finned tubes, are finding wider application.

Plate-style heat exchangers, long used in the milk industry, are now finding work in chemical and petroleum plants; an unusual plate heat exchanger uses sheets of 16-gage seamless metal. The sheets are embossed to form internal crossing channels, which carry the heat-transfer media.

Also, with a growing concern for water quality and availability, air-cooled exchangers are being given added consideration.

CONSTRUCTION MATERIALS

Many metals are employed in the fabrication of various heat exchangers; however, carbon steels and alloy steels are used generally because of the strength they offer, es-

pecially when the heat exchanger also is operated as a pressure vessel. Brass and copper are excellent heat conductors and, because they are such good conductors, both find wide acceptance in the manufacture of heat exchangers.

The problem of corrosion is carefully considered in the selection of exchanger construction materials. An expensive material may be selected for use with a corrosive tube-side fluid; a less expensive material may be selected for use on a less corrosive shell side.

Special corrosive problems (e.g., irradiation) may call for graphite, glass, ceramic, aluminum, nickel, bimetallic, tantalum, silver, gold or bronze as material.

MAINTENANCE PROBLEMS

A heat exchanger may encounter many stress and corrosion problems as well as problems of fluid mechanics and heat transfer. One major problem is the formation of scale deposits on either side of a barrier wall. These deposits offer resistance to heat transfer (often of such magnitude that the exchanger must be periodically removed from service for cleaning).

Another area of maintenance concerns allowance for differential thermal expansion of metallic parts; most operating difficulties occur during startup or shutdown of equipment. A generating plant initially may introduce coolant fluid during startup, and slowly add the hotter fluid. When an exchanger is to be shutdown, the hot fluid generally is shut off first. The operator may drain any steam con-

densate from the exchanger prior to a startup or shutdown; condensate introduces the possibility of water "hammer" caused by steam forcing trapped water through the lines at a high velocity.

TEMPERATURE DISTRIBUTION

One basic law of thermodynamics states that heat always flows in the direction of decreasing temperature, with several physical processes being involved in heat transfer. A temperature drop within a heat exchanger is required to carry the heat from a warm fluid to a heating surface. A second temperature drop is needed to carry the heat through the barrier (between the warmer and colder fluids), and a third temperature drop is required to move the heat from the surface of the colder fluid into its bulk.

Heat conduction is the major physical process involved in heat flow through the solid wall and from one surface to another. The conduction process is supplemented by convection (i.e., the fluid carries heat along as it flows through the heat exchanger).

Nature provides two types of fluid flow. In the first, called laminar flow, fluid particles move along in an even pattern, side by side. In the second, called turbulent flow, waves and vortices (eddies) are continuously formed and destroyed.

Tube diameter, velocity and fluid viscosity determine whether flow is laminar or turbulent. Flow may be laminar when velocity is low, tube diameter is small and viscosity

is large. Laminar flow is common in oil coolers, for example, because oil has high viscosity. Heat exchangers using fluids such as water or various gases usually must contend with turbulent flow.

Heat transfer, from a fluid to a tube wall in a laminar flow condition, results mainly from conduction. Also, it is limited mainly by conductivity of the fluid and tube diameter. Liquids, which have greater heat conductivity values than gases, can transfer heat more rapidly. Liquid metals possess especially large heat conductivity values; for this reason, they are used in applications in which large amounts of heat have to be transferred at small temperature differences. Liquid metals are especially appropriate for heat exchangers in certain nuclear reactors.

Turbulent flow depends upon fluid velocity to transfer heat from the fluid to the wall of the exchanging device. Because of its turbulent action, and its velocity, heat transfer in turbulent flow normally is greater than in laminar flow.

STANDARDIZATION

The American Standards Association, the American Institute of Chemical Engineers, the Tubular Exchangers Manufacturers' Association, and the American Petroleum Institute are presently active in a campaign to have heat exchangers become more standard in design and be made available at less expensive prices.

Included as Data Tables 16-7-1, 16-7-2 and 16-7-3 (in

the Procedures) are design engineer specification forms used for construction and procurement of shell-and-tube exchangers, air-cooled exchangers, and double-pipe, fin-type exchangers. The forms are included to offer the student information on specifications considerations for heat exchangers.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

1. Use parameters and characteristics provided by instructor to specify a shell-and-tube heat exchanger on Data Table 16-7-1. Would this kind of heat exchanger find application in a nuclear power plant? Where?

2. Use parameters and characteristics provided by instructor to specify an air-cooled heat exchanger on Data Table 16-7-2. Would this kind of heat exchanger find application in a nuclear power plant? If so, where?
3. Use parameters and characteristics provided by instructor to specify a double-pipe, fin-type heat exchanger on Data Table 16-7-3. Would this kind of heat exchanger find application in a nuclear power plant? If so, where?

DATA TABLE 16-7-1
SHELL-AND-TUBE HEAT EXCHANGER

CUSTOMER						JOB NO.	
PLANT						ITEM NO.	
SERVICE						FILE NO.	
SIZE ,	TYPE			CONNECTED IN		P. O. NO.	
GROSS SURFACE/UNIT		SHELLS/UNIT			SURFACE/SHELL		
PERFORMANCE OF ONE UNIT							
		SHELL SIDE			TUBE SIDE		
FLUID CIRCULATED							
TOTAL FLUID ENTERING	LB/HR						
VAPOR	LB/HR						
LIQUID	LB/HR						
STEAM	LB/HR						
NON CONDENSABLES	LB/HR						
FLUID VAPORIZED OR CONDENSED	LB/HR						
STEAM CONDENSED	LB/HR						
GRAVITY-LIQUID							
VISCOSITY-LIQUID							
MOLECULAR WEIGHT-VAPORS							
SPECIFIC HEAT-LIQUIDS				BTU/LB/°F			BTU/LB/°F
LATENT HEAT-VAPORS				BTU/LB			BTU/LB
TEMPERATURE IN				°F			°F
TEMPERATURE OUT				°F			°F
OPERATING PRESSURE				PSI			PSI
NUMBER OF PASSES PER SHELL							
VELOCITY				FT/SEC			FT/SEC
PRESSURE DROP				PSI			PSI
FOULING RESISTANCE							
HEAT EXCHANGED - BTU/HR				MTD (CORRECTED)			
TRANSFER RATE - SERVICE				BTU/HR/SQ FT/°F	SURFACE/UNIT		
CONSTRUCTION							
DESIGN PRESSURE				PSI			PSI
TEST PRESSURE				PSI			PSI
DESIGN TEMPERATURE				°F			°F
TUBES	NO.	O.D.		BWG	LENGTH	PITCH	
SHELL		I.D.	O.D.				
SHELL COVER					FLOATING HEAD COVER		
CHANNEL					CHANNEL COVER		
TUBE SHEETS - STATIONARY					FLOATING		
BAFFLES - CROSS			TYPE		THICKNESS	SPACING	
BAFFLES - LONG			TYPE		THICKNESS		
TUBE - SUPPORTS					THICKNESS		
GASKETS							
CONNECTIONS - SHELL IN			OUT		RATING & FACING	PSI	
CHANNEL IN			OUT		RATING & FACING	PSI	
CORROSION ALLOWANCE - SHELL SIDE					TUBE SIDE		
CODE REQUIREMENTS							
WEIGHTS - EACH SHELL				BUNDLE	FULL OF WATER		
NOTE - INDICATE AFTER EACH PART WHETHER STRESS REL'VED S.R. AND/OR RADIOGRAPHED R.P.							
REMARKS - STACKED EXCHANGERS TO BE FURNISHED COMPLETE WITH BOLTS AND GASKETS							
CLEANING							
PAINTING							
INSULATION							

DATA TABLE 16-7-2
AIR-COOLED HEAT EXCHANGER

CUSTOMER			JOB NO.
PLANT			ITEM NO.
SERVICE			FILE NO.
NO. REQD.	SIZE		P. O. NO.
TYPE			NO. OF BAYS
SURFACE/ITEM	EXTERNAL		BARE TUBE SQ. FT.
HEAT EXCHANGED	BTU/HR		EFFECTIVE MTD °F
TRANSFER RATE EXTERNAL SURFACE			BARE TUBE SURFACE
PERFORMANCE DATA			
TUBE SIDE			
FLUID CIRCULATED			TEMPERATURE IN °F
TOTAL FLUID ENTERING	LBS/HR		TEMPERATURE OUT °F
VAPOR			INLET PRESSURE PSIG
LIQUID			GRAVITY - LIQUID
STEAM			VISCOSITY CPS @ °F
NON-CONDENSABLES			VISCOSITY CPS @ °F
VAPOR CONDENSED			MOLECULAR WEIGHT
STEAM CONDENSED			SPECIFIC HEAT BTU/LB °F
DENSITY VAP. LIQUID MIXT	LBS/CU. FT.		LATENT HEAT BTU/LB
CONDUCTIVITY	BTU FT/HR. SQ. FT. °F/I		ALLOW PRESS. DROP PSI
FOULING RESISTANCE	S. HR. SQ. FT. °F/BTU		DESIGN PRESS. DROP PSI
AIR SIDE			
AIR QUANTITY	ACFM		TEMPERATURE IN °F
AIR QUANTITY/FAN	ACFM		TEMPERATURE OUT °F
			ALTITUDE FT.
CONSTRUCTION			
DESIGN PRESSURE	PSI	TEST PRESSURE PSI	DESIGN TEMPERATURE °F
SECTION		HEADER	TUBE
SIZE	BOWS	TYPE	MATERIAL
NO. BAY		MATERIAL	OD IN.
ARRANGEMENT		NO. PASSES	NO. / SECTION
		PLUG	LENGTH FT.
		GASKET MATERIAL	PITCH IN. △
		CORROSION ALLOWANCE	IN. FIN
MISC.		SIZE INLET NOZZLE	IN. MATERIAL
STRUCTURE		SIZE OUTLET NOZZLE	IN. OD
		RATING	NO. IN
		CODE—	TYPE
MECHANICAL EQUIPMENT			
FAN		DRIVER	SPEED REDUCER
TYPE		TYPE	TYPE
NO. BAY HP/FAN		NO. BAY HP/DRIVER	NO. BAY
DIAMETER FT. RPM		RPM	MODEL
NO. BLADES PITCH		ENCLOSURE	AGMA HP RATING
BLADE MATERIAL		VOLT PHASE CYCLE	RATIO
HUB MATERIAL			
REMARKS			
			WEIGHT LBS

DATA TABLE 16-7-3
HEAT EXCHANGER (DOUBLE-PIPE, FIN-TYPE)

CUSTOMER			JOB NO.
PLANT			ITEM NO.
SERVICE			FILE NO.
SIZE	TYPE		P. O. NO.
PERFORMANCE ONE UNIT			
DESIGN CONDITIONS	**SHELL SIDE**		**TUBE SIDE**
FLUID CIRCULATED			
TOTAL FLOW LBS/HR			
VAPOR ENTERING LBS/HR			
LIQUID ENTERING LBS/HR			
VAP. OR COND. & N. C. LBS/HR			
SPECIFIC GRAVITY @ 60° F			
SPECIFIC HEAT @ 60° F	BTU/LB °F		BTU/LB °F
LATENT HEAT BTU/LB			
VISCOSITY	CP @ °F		CP @ °F
MOLECULAR WEIGHT - LIQ.			
THERMAL CONDUCTIVITY			
TEMPERATURE - IN °F	°F		°F
TEMPERATURE - OUT °F	°F		°F
OPERATING PRESS.	PSIA		PSIA
WATER—VAP. OR COND. LBS/HR			
VELOCITY @ AVG. TEMP	FPS		FPS
PRESSURE DROP	PSI		PSI
HEAT EXCHANGED BTU/HR	CORRECTED MTD		
TRANSFER RATE SERVICE	CLEAN		
FOULING RESISTANCE SHELL	TUBES	CROSS	WET
SURFACE/SECT. SQ. FT	NO. SECT.	TOTAL SURFACE/UNIT	SQ. FT
CONSTRUCTION			
DESIGN PRESSURE	PSIG		PSIG
TEST PRESSURE	PSIG		PSIG
DESIGN TEMPERATURE	°F		°F
CORROSION ALLOWABLE			
CONNECTIONS			
GASKETS			
HOOK UP PARALLEL BANKS			
SECTION IN SERIES			
SHELL COVER			
BAFFLE PLATE NO.	HEIGHT		
DIMENSIONS LENGTH	WIDTH	HEIGHT	
TUBING ARRANGEMENT	WIDE	HIGH	
FILLED UPON DESIGN COND. IS GIVEN MAX. TEMP. OF ELEMENT WILL NOT EXCEED °F			
REMARKS			

Eckert, E.R.G. and Drake, R.M., Jr. Analysis of Heat and Mass Transfer. New York: McGraw-Hill, 1973.

El-Wakil, M.M. Nuclear Heat Transport. Scranton, PA: International, 1971.

Harrer, J.M. Nuclear Power Reactor Systems Handbook. Vol. 1, USAEC Publication TID-25952-PI(1973) and Vol. 2, USNRC Publication TID-25952-P2(1974).

1. List and describe five classes of heat exchangers (presented in this module):

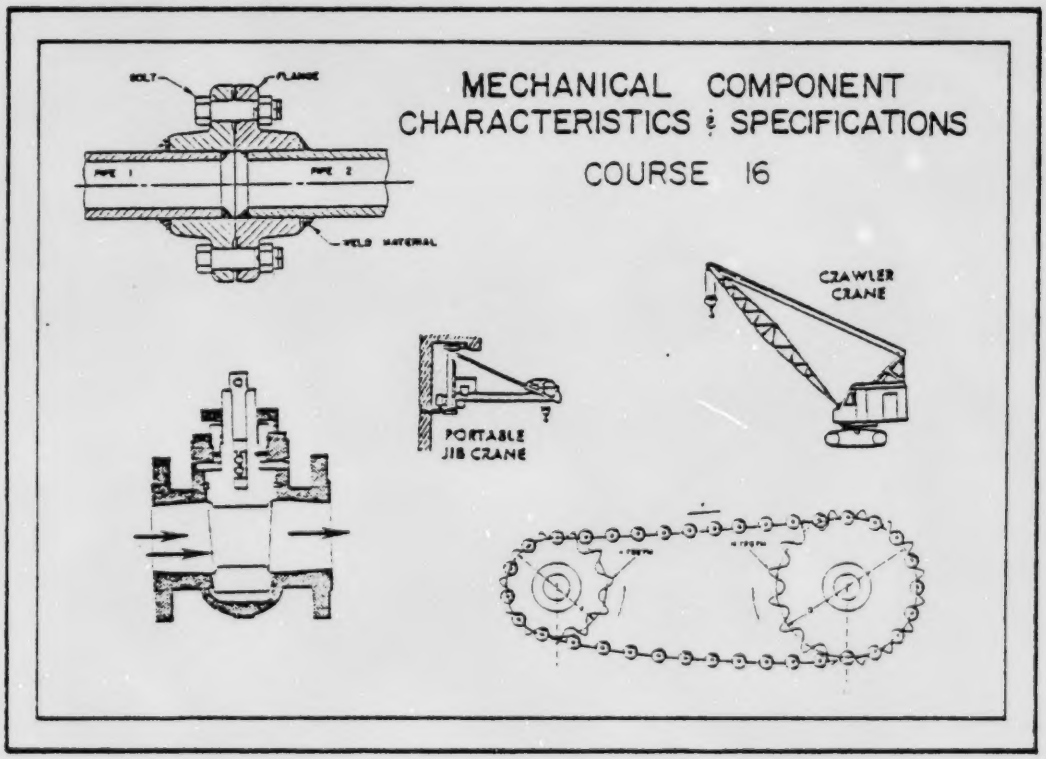
2. List three heat exchanger maintenance problems and their solutions (as given in this module):

3. Describe two thermal characteristics of a heat exchanger:

4. Note where and how temperature changes occur in heat transfer (from one medium, through a barrier, to a second medium):

NUCLEAR TECHNOLOGY

MODULE 16-8 PRESSURE VESSEL CHARACTERISTICS AND SPECIFICATIONS



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4201 LAKE SHORE DRIVE WACO, TEXAS

COURSE MODULES

COURSE 16 MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS

MODULE 16-1 Pump Characteristics and Specifications

MODULE 16-2 Piping Characteristics and Specifications

MODULE 16-3 Valve Characteristics and Specifications

MODULE 16-4 Fastener Characteristics and Specifications

MODULE 16-5 Lifting and Handling Equipment Characteristics and Specifications

MODULE 16-6 Rotating Equipment Characteristics and Specifications

MODULE 16-7 Heat Exchanger Characteristics and Specifications

MODULE 16-8 Pressure Vessel Characteristics and Specifications

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Waco, Texas 76710

INTRODUCTION

The National Board of Boiler and Pressure Vessel Inspectors is "organized for the purpose of promoting greater safety to life and property by ... maintaining uniformity in the construction, installation and inspection of boilers and pressure vessels..." On page 12 of their information booklet (NB21 Rev. 0) they state:

> Nuclear power plant components, parts, appurtenances, valves and piping subassemblies built or used in the United States must be built to meet or surpass requirements of the ASME* Code, Section III, "Nuclear Power Plant Components." Manufacturers of these items must undergo an ASME survey during which they must demonstrate their ability to design and fabricate to the ASME Code and National Board requirements.

No boiler or pressure vessel receives the stamp of approval until it conforms with the rules formulated by the Boiler and Pressure Vessel Committee of the American Society of Mechanical Engineers. This module describes the materials characteristics and construction of such pressure vessels.

MODULE PREREQUISITES

The student should have completed Module 10-1, "Power Plant Fundamentals."

* American Society of Mechanical Engineers.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Describe the principal material used to construct pressure vessels.
2. List codes and specifications applicable to pressure vessels.
3. Describe significance of ASME Code to nuclear power plant pressure vessels.
4. List tests that must be performed to show compliance with codes and specifications.
5. Describe hydrostatic testing performed to ensure that pressure vessel meets its specifications.

A pressure vessel is any container (usually cylindrical or spherical, and made of metal) built to withstand pressure exerted by materials within it. Special emphasis is given to the strength of the vessel to prevent an explosion (which might result from rupture) that could be dangerous to life and property.

Pressure vessels intended to carry only low pressures generally are constructed of tubes and sheets rolled to form cylinders. Pressure vessels intended to carry high pressures have to provide sufficient strength. Application as well as fabrication techniques dictate vessel diameter, wall thickness, and the type of cylinder ends used. For increased strength, heavy forgings may be welded together but, for most vessels, rolled sheet and formed ends are fastened together with rivets.

In the determination of shell stress, certain variables must be considered. Such considerations include the type of end construction of the cylinder or vessel (whether welded, riveted or cast) and kind of material used (whether pliable or brittle); also, the conditions of operation, including pressure and temperature variations and limitations, must be considered.

Most pressure vessels are designed to withstand internal pressure, but occasionally external pressure is a concern. If external pressure is a factor, material characteristics as well as design must be adapted to this reverse requirement.

When in service, boiler drums, shells, braces, stays and tubes all are subject to continuous stress, elevated temperatures and contamination. All materials used in the

construction of the vessel demand a detailed study 1) of forces that will be exerted on the various parts, 2) of temperatures to which the parts will be exposed and 3) of contaminants the internal surfaces must resist or tolerate.

BOILER CONSTRUCTION MATERIALS

Steel used in the construction of boilers must be of first quality with all constituents carefully controlled. Unlike steel used in general construction, boiler steel must withstand elevated temperatures (a more serious characteristic than pressure). Good grades of low-carbon steel can maintain and even increase in strength up to a temperature of 700°F. Above that level, the strength of carbon steel decreases rapidly, this higher temperature necessitates alloy steels (adding a small percentage of molybdenum into the steel used to manufacture superheater tubes, piping and valves increases the ability of these parts to withstand high temperature increases).

Chemical analyses of alloying materials and impurities in steel are used to determine steel quality. Carbon is reduced to approximately 0.25 percent in boiler plate. A larger percentage of carbon causes the steel to harden and crack under the influence of elevated pressures and temperatures. (More than 0.25 percent carbon may be tolerated in flanges and fittings.)

Common impurities found in steel are sulfur, phosphorous, manganese and silicon. Sulfur reduces flexibility of steel and makes it hard to work, especially when hot. Phosphorous

makes steel hard and, to some extent, strong; it is undesirable in boiler plate, however, because it lessens the plate's ability to withstand vibratory forces. Manganese makes steel hard and difficult to cut and work, but is considered desirable because it combines with - and lessens the effect of - the sulfur. Silicon has a tendency to make steel hard but, because it does not decrease tensile strength, is considered desirable.

Chemical analyses are also used to control introduction into the alloy of chromium, nickel, molybdenum and other substances used in making steel for high-temperature boiler tubes.

Steel for the construction of boilers is manufactured in two different processes: bessemer and open-hearth. The bessemer process was, for years, the principal method of making steel. Primarily, the process consisted of burning the impurities out of molten pig iron in a bessemer converter.

The open-hearth process consists of heating pig iron and scrap iron by exposing them to the heat of a gas flame until the carbon and impurities are reduced to a desired percentage.

Steel processed in an open-hearth has an advantage over bessemer processed steel because almost any characteristic can be obtained. The slowness with which the open-hearth process moves makes possible analyses of samples and continued reduction of impurities. These processes add the necessary material in the precise quantities needed to get the desired percentage of alloys.

Copper plays no important part in boiler construction because it is expensive and because it has low tensile strength. Brass and other alloys used in making many small boiler fittings and valves, provide high resistance to corrosion.

NUCLEAR STRUCTURAL MATERIAL

A nuclear reactor vessel must contend with fuel, moderators, coolant, control systems, shielding and structural material. The structural materials should have good mechanican properties at high temperature and possess substantial corrosion resistance. Materials in the core and reflector of a thermal reactor should have low neutron-capture cross sections. Magnesium, aluminum and zirconium have low neutron-capture cross sections, but stainless steel - which has a slightly higher cross section - is more frequently used because of its outstanding mechanical and corrosion resistance properties.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME) CODE

Relevant sections of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code include the following:

Section I. Power Boilers.
Section II. Material Specifications.
  Part A - Ferrous Materials.
  Part B - Nonferrous Materials.
  Part C - Welding Rods, Electrodes and Filler Metals.
Section III. Division 1 and Division 2 - Nuclear Power Plant Components: General Requirements.
Section III. Division 1.
  Subsection NB - Class 1 Components.
  Subsection NC - Class 2 Components.

Subsection ND - Class 3 Components.
Subsection NE - Class MC Components.
Subsection NF - Component Supports.
Subsection NG - Core Support Structures.
Appendices.

Section III. Division 2 - Code for Concrete Reactor Vessels and Containments.

Section IV. Heating Boilers.

Section V. Nondestructive Examination.

Section VI. Recommended Rules for Care and Operation of Heating Boilers.

Section VII. Recommended Rules for Care of Power Boilers.

Section VIII. Pressure Vessels.
Division 1.
Division 2 - Alternative Rules.

Section IX. Welding and Brazing Qualifications.

Section X. Fiberglass-Reinforced Plastic Pressure Vessels.

Section XI. Rules for Inservice Inspection of Nuclear Power Plant Components - Division 1.

The rules of the ASME Code for the safe construction of boilers are without legal status until adopted by a state, municipality, or other legally responsible body (such as the Nuclear Regulatory Commission). States and cities that have in fact legally adopted the Code have appointed chief inspectors who, collectively, form the National Board of Boiler and Pressure Vessel Inspectors who administer the Code.

The Code primarily covers only new boiler construction - and does not include many types of repairs. The National Board has created a National Board Inspection Code that

makes suggestions for uniform laws pertaining to inspection; this Code includes "Rules for Repairs by Fusion Welding."

The National Board Rules, like the ASME Code, only have legal status when properly authenticated by governmental authority.

The National Bureau of Casualty and Surety Underwriters issues a booklet titled Synopsis of Boiler Rules and Regulations that lists the states and cities that have laws covering installation and operation of steam boilers. Additionally, the booklet includes names of administrative officials as well as licenses, fees and inspections required.

To satisfy requirements of the Code, boilers must be erected by or under the supervision of an organization authorized to use the ASME power boiler stamp or the ASME assembly stamp. Requirements governing the authority to use these stamps are listed in the Code.

BOILER INSPECTION REQUIREMENTS

A boiler manufactured and erected in compliance with the ASME Code must be periodically inspected at certain stages of installation by an authorized inspector. An authorized inspector is a person licensed by the state or city in which the boiler is erected and who has been commissioned by the National Board as an inspector. The greater part of inspection work (in nonnuclear installations) is accomplished by insurance companies who employ inspectors qualified to comply with Code inspector requirements.

The inspector, who must be satisfied that boiler con-

struction work complies with the Code, endorses data sheets pertaining to the unit, and witnesses stamping of the boiler pressure parts. Actual stamping usually is done in a shop. All data reports relating to boiler shop fabrication are endorsed and authenticated by the inspector who monitored the work as it progressed. The inspector covering field work (installation) authenticates data reports pertaining to field assembly and erection, and witnesses any stamping required by governmental authority.

The field inspector must be able to certify that all welding, construction and materials conform to the Code. In part, the inspector must rely on certification of the manufacturer or contractor, whom the Code makes responsible for the quality of welding.

The inspector must be satisfied that welding operators and welding procedures are properly qualified. The inspector also must have an opportunity to inspect welding as it progresses and be satisfied as to its quality.

The number of inspections, the times of inspections and the duration of inspections are usually determined by agreement between the inspection agency and the manufacturer before actual work on the boiler begins. The authorized inspector also must witness hydrostatic tests on the unit, with field data sheets being authenticated at that time.

Continuous inspections are required by the manufacturer to ensure that all workmanship meets established standards of quality. Inspections for erecting organization are made by job superintendents, welding technicians, foremen and welding operators. Some of these inspections are completed in the company of an authorized inspector.

The objectives of frequent and sometimes continuous inspections are to ensure that:

Each operator is qualified under the Code for the weld made.

Procedure specifications are rigorously followed.

Each joint is accurately aligned and fitted before welding is started.

Each weld bead is cleaned of slag and the weld freed of slag porosity and undercutting.

Finished weld is of correct contour without undercutting or overlapping.

Certain paragraphs of the ASME Code outline requirements for making radiographs of welds, and establish standards for welding acceptance. Fusion-welded circumferential joints in pipes, tubes and headers must also be radiographed when their dimensions exceed certain sizes. (A radiograph is a shadow or image picture made by using short wave radiations, such as x-rays or gamma rays, to penetrate opaque substances.)

More obvious weld defects may be observed on a radiograph without difficulty. Detection of small cracks and slag inclusions requires the services of a technician with considerable training and experience in radiograph interpretation.

Handhole and manhole fittings are provided in boiler components for access to tubes, and flanged joint assemblies also are items for inspection.

Dirt and other foreign matter can be the cause of problems during boiler operations. Various fabrication shops take precautions to ensure that drums, tubes, headers, pipes and other pressure parts remain internally clean throughout construction. All parts demanding such attention are sealed at the ends with metal caps and covered with tape. The use of oil on water surfaces of boilers is avoided (a

water-soluble lubricant is used on tube expanders and tools for machining tube ends).

Erection crews perform additional inspections to ensure the exclusion of dirt and foreign matter after the caps and tapes are removed.

A hydrostatic test at one and one-half times design pressure is completed after all pressure-part connections have been made. Water being fed into the boiler, which must be clean and at a temperature of not less than 70°F and not more than 100°F, is vented at every possible connection to allow fluid to fill every circuit. Nondrainable heaters and superheaters are filled with demineralized water or condensate, if available.

When the boiler is filled, hydrostatic pressure is applied by a pump constructed especially for testing purposes. While the water is being pumped, continuous inspection of the boiler is made to observe any leakage (which will require repair or which might become dangerous).

Test pressures are held for six to eight hours, or long enough to observe the most minute leak. Following this holding period, pressure is retained to complete a final inspection where every area of the pressure system is viewed for leakage and repaired as necessary to make the unit completely watertight.

EXERCISES

None.

MATERIALS

None.

PROCEDURES

SPECIFICATIONS

Data Tables 16-8-1 and 16-8-2 are examples of procurement specification forms used by engineers when specifying requirements for either a vertical or a horizontal vessel.

1. Use pressure vessel parameters and characteristics provided by instructor to specify (On Data Table 16-8-1) a vertical pressure vessel. Can you suggest where in a nuclear power plant such a pressure vessel might be used?
2. Use pressure vessel parameters and characteristics provided by instructor to specify (on Data Table 16-8-2) a horizontal pressure vessel. Can you suggest where in a nuclear power plant such a pressure vessel might be used?

DATA TABLE 16-8-1

VERTICAL VESSELS

CUSTOMER				JOB NO.	
PLANT				ITEM NO.	
SERVICE				FILE NO.	
P.O. REQD.		SIZE		P. O. NO.	
PRESS. (PSIG)	DESIGN:	OPER.	CORROSION ALLOWANCE		
TEMP. (°F)	DESIGN:	OPER.	STRESS RELIEVE:	X-RAY:	
WELDING EFFICIENCY: SHELL	%, HEADS		% HEADS:	S'RUP	P & O
MAX. ALLOW. PRESS. (NEW & COLD)			PSIG		
HYDROSTATIC TEST	PSIG				
PHYSICAL/CHEMICAL TEST					

MECHANICAL DATA

HEADS	THICKNESS	IN	MATERIAL	
SHELL	THICKNESS	IN	MATERIAL	
SKIRT	THICKNESS	IN	MATERIAL	
LINER	THICKNESS	IN	MATERIAL	
PRESS. PIPE			PLG. STEEL	
POUND	WEIGHT EMPTY		OPER.	
DATA	WIND		EARTHQUAKE	

NOZZLE SCHEDULE

MK	SERVICE	NO	SIZE	RATING	FACE
A	INLET				
B	OUTLET				
C	DRAIN				
D	RELIEF				
E	MANWAY W/BP				
F	LEVEL				
G					
H					

ACCESSORIES	BY	REF. DWG.
LADDER W. CAGE		
PLATFORMS		
INSULATION RINGS		
MANWAY HINGED DAVIT		
BASE RING		
MIST ELIMINATOR		
LOUVER BREAKER		

REMARKS:

NOZZLE 2" & SMALLER
PROJ. 3" & LARGER

VESSEL SHALL BE CONSTRUCTED ACCORDING TO THE LATEST REVISION OF THE ASME CODE FOR UNFIRED PRESSURE VESSELS

ASME CODE STAMP YES NO

CLEANING

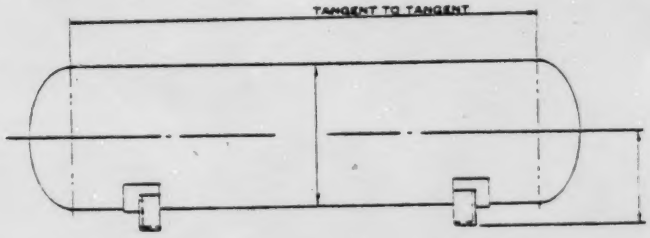
PAINTING

INSPECTION BY

DATA TABLE 16-8-2

HORIZONTAL VESSELS

CUSTOMER	JOB NO.
PLANT	ITEM NO.
SERVICE	FILE NO.
NO. REQD. SIZE:	P.O. NO.



DESIGN DATA	
PRESS. (PSIG) DESIGN:	OPER.
TEMP. (°F) DESIGN:	OPER.
CORROSION ALLOWANCE	
STRESS RELIEVE	X-RAY
WELDING EFFICIENCY: SHELL	% HEAD %
MAX. ALLOW. PRESS. (NEW & COLD)	PSIG
HYDROSTATIC TEST:	
PHYSICAL/CHEMICAL TEST	

NOZZLE SCHEDULE					
MK	SERVICE	NO.	SIZE	RATING	FACE
A	INLET				
B	OUTLET				
C	DRAIN				
D	RELIEF				
E	MANWAY W/BF				
F	LEVEL				
G					
H					

REMARKS:

MECHANICAL DATA	
HEADS THICKNESS IN.	MATERIAL
SHELL THICKNESS IN.	MATERIAL
LINER THICKNESS IN.	MATERIAL
PRESS. PIPE:	FLG. STEEL:
FOUND. WEIGHT EMPTY:	OPER.
DATA WIND:	EARTHQUAKE:

ACCESSORIES	BY	REF. DWG.
LADDER		
PLATFORM		
INSULATION CLIPS		
SADDLES		
SUPPORTS		

NOZZLE ___ 2" & SMALLER
POOL ___ 3" & LARGER

VESSEL SHALL BE CONSTRUCTED ACCORDING TO THE LATEST REVISION OF THE ASME CODE FOR UNFIRED PRESSURE VESSELS.

ASME CODE STAMP YES NO

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INSPECTION BY:

Babcock and Wilcox Co. Steam: Its Generation and Use. New York: B & W, 1975.

Harvey, John F. Pressure Vessel Design: Nuclear and Chemical Applications. Princeton, NJ: D. Van Nostrand Company, Inc., 1967.

Power Generation Systems. By the editors of Power. New York: McGraw-Hill Book Company, Inc., 1958.

Thielsen, Helmut. Defects and Failures in Pressure Vessels and Piping. New York: Reinhold Publishing Corporation, 1962.

Waite, Harold H., ed. Pressure Vessels and Piping: Design and Analysis. Four Volumes. New York: American Society of Mechanical Engineers, 1972.

Woodruff, Everett B. and Lammers, Herbert B. Steam Plant Operation. New York: McGraw-Hill Book Company, 1975.

1. Briefly describe material identified in this module as best suited for pressure vessels with internal environments up to 700°F:

2. Briefly describe material identified in this module as best suited for pressure vessels with internal environments above 700°F:

3. Briefly describe hydrostatic testing of a boiler (as described in this module):

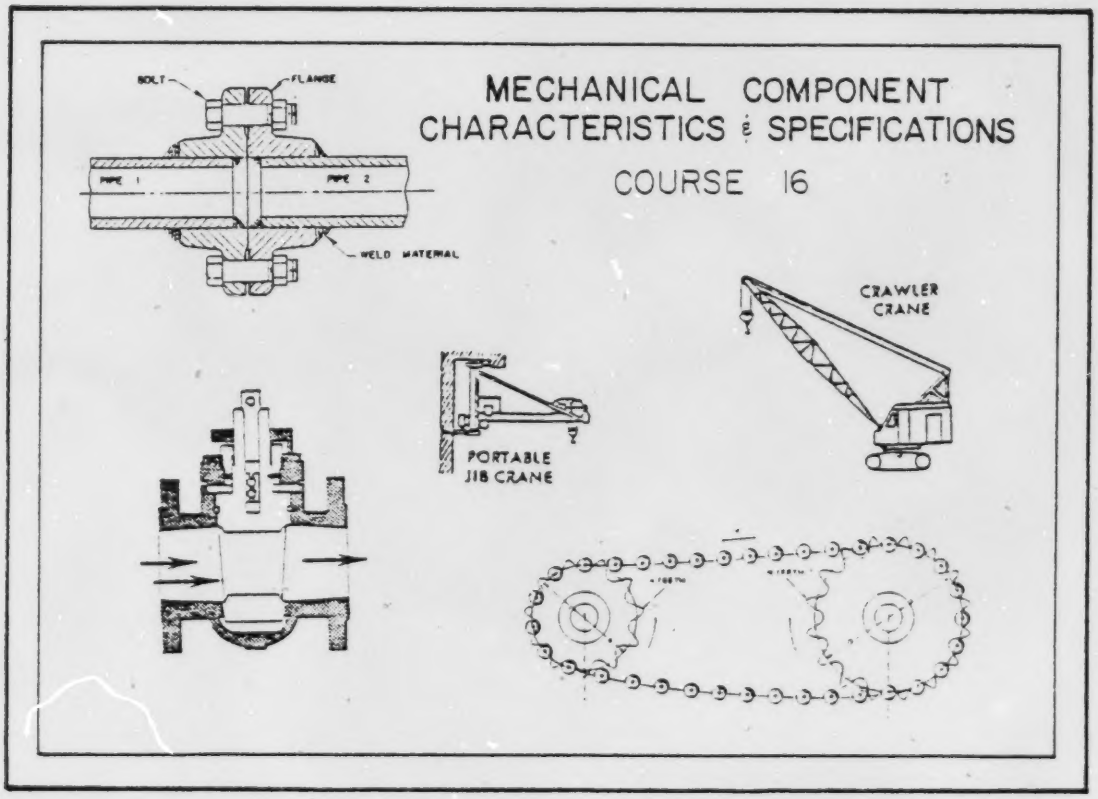
4. In order of importance, list the three pressure vessel characteristics noted in this module:

5. Describe significance of ASME Code, Section III, "Nuclear Power Plant Components," to pressure vessel approval by the Nuclear Regulatory Commission:

NUCLEAR TECHNOLOGY

INDEX

COURSE 16 - MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS



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NUCLEAR TECHNOLOGY SERIES

INDEX

for

COURSE 16, MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS (EIGHT MODULES)

NOTE: Each module in this Course is numbered separately, and the page numbers begin with page 1 in each module. Therefore, this Index lists for each entry the module number (underlined), followed by a comma and the page number. Figures and tables are listed by their numbers, followed by the module and page number in parentheses. A Master Index is available in a separate volume. This general index merges all index entries from the 35 Nuclear Courses. It is a valuable research tool, with which the student or researcher can locate all the references to any subject within the 35 Courses.

Adhesive
  as fastener, 16-4, 15
American National Standards Institute
  and standardization procedures, 16-1, 10
American Nuclear Society
  functions of, 16-1, 12
American Society of Mechanical Engineers
  Code of, 16-8, 6, 7
  and standards for products, 16-1, 9
American Society for Quality Control
  functions of, 16-1, 12
American Society for Testing and Materials
  and standard test methods, 16-1, 10, 11

Boiler
  construction materials, 16-8, 4, 5
  hydrostatic testing of, 16-8, 11
  inspection, 16-8, 8-10
  radiographic weld inspection of, 16-8, 10
Bolt
  for fastener, 16-4, 8
Bridge
  fuel-storage handling, 16-5, 20, 21
  main fuel-handling, 16-5, 15-20

Canal
  refueling, 16-5, 4
Collar
  fastener, 16-4, 14
Conveyors
  types of, 16-5, 4-6
Coupling
  for fastening, 16-4, 15
Cranes
  description of, 16-5, 9, 10
  types of, 16-5, 10-12

Derrick
  guy, 16-5, 10, 11
  tower, 16-5, 11
Drive mechanism
  chain, 16-6,
  speed reducing, 16-6, 5; Fig. 16-6-4 (16-6, 6)
  universal, 16-6, 7

Elevating machines
  discussion of, 16-5, 7, 8
Elevator
  fuel handling, 16-5, 23

Fasteners
  corrosion of, 16-4, 7
  design specifications of, 16-4, 4
  product specifications of, 16-4, 3
  threaded, 16-4, 5, 5-7
Fuel
  new, shipment of, 16-5, 22
  transfer system, 16-5, 20, 21

Handling equipment
  and material characteristics, 16-5, 3
  for use in reactor plants, 16-5, 12, 13
Handling systems
  conveyor, 16-5, 4
  fuel, 16-5, 13, 14
  monorail, 16-5, 9
  types of, 16-5, 4
Heat exchangers
  classification of, 16-7, 3, 4
  conduction in, 16-7,
  design of, 16-7, 5
  flow in, 16-7,
  function of, 16-7, 3
  heat transfer in, 16-7, 8
  maintenance for, 16-7, 6
  materials for, 16-7, 5, 6
  standardization of, 16-7, 8, 9

Industrial truck
  discussion of, 16-5, 8
Institute of Electrical and Electronics Engineers
  functions of, 16-1, 11
Interlocks
  in fuel transfer system, 16-5, 22

Jib
  in crane, 16-5, 9, 10

Joints
expansion, 16-2, 11, 12
pipe, 16-2, 9-11

Key and spline
fastener, 16-4, 15

Load monitoring system
functions of, 16-5, 17, 18

Manufacturers Standardization Society of the Valve and Fittings Industry
functions of, 16-1, 13
Mast
in fuel-handling bridge, 16-5, 15-17
Materials Handling Equipment Distributors Association
functions of, 16-1, 13
Metal stitching
as fastener, 16-4, 15

National Board Inspection Code
and boiler repair, 16-8, 7, 8
Nut
for fastener, 16-4, 8, 9

Pipe
flexibility of, 16-2, 13
steel, classification of, 16-2, 5-8
Pressure vessel
description of, 16-8, 3, 4
Pumps
centrifugal, 16-1, 3-5
characteristic curve for, 16-1, 7, 8
classification of, 16-1, 3
materials for, 16-1, 7
mechanical, 16-1, 1
reciprocating, 16-1, 5, 6
rotary, 16-1, 6, 7

Reactor cavity
function of, 16-5, 14
Retainer ring
fastener, 16-4, 9
Rivet
fastener, 16-4, 10
Rotating equipment
bearings, 16-6, 9
components of, 16-6, 3
control mechanism for, 16-6, 8
design of, 16-6, 4, 5
drive mechanism of, 16-6, 5-7
functions of, 16-6, 3
inspection of, 16-6, 9, 10
shaft, bowing of, 16-6, 9; turbine, 16-6, 11
specifications for, 16-6, 10

Screw
fastener, 16-4, 8
thread, standardization of, 16-4, 4, 5
Sleeve
fastener, 16-4, 14

Turbine generator
in nuclear plant, Fig. 16-6-2 (16-6, 4)

Union
for pipe joints, 16-2, 9-11

Valves
angle, 16-3, 8, 9
check, 16-3, 9-11
control, 16-3, 12
functions of, 16-3, 3, 4
gate, 16-3, 4-6; quick-opening, 16-3, 6, 7
globe, 16-3, 8, 9
needle, 16-3, 9; Fig. 16-3-5 (16-3, 10)
plug, 16-3, 7, 8
relief, 16-3, 3
structure of, 16-3, 3

Washer
for fastener, 16-4, 9
Wedge
component of gate valve, 16-3, 5
Welding
characteristics of, 16-4, 12
classifications of, 16-4, 11
Nuclear Regulatory Commission Standards for, 16-4, 12